Threats to Groundwater, measured by means of the Environmental Potential Risk Indicator for Pesticides (EPRIP)

Mandy Häger

Norwegian University of Life Sciences
Department of Plant and Environmental Sciences
Master Thesis 30 credits 2010

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By
Mandy Häger

Supervised by
Ole Martin Eklo
Tor Arvid Breland

Norwegian University of Life Sciences
Department of Plant and Environmental Sciences (IPM)
Master thesis 30 credits

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FOREWORD

The following paper addresses the issue of groundwater contamination, caused by pesticides used in agricultural production. Groundwater is an important resource, which faces an increasing pressure from intensive land use and consumption. In some parts of the world, water is already scarce and it is therefore important to take care of the water resources we still have. I have chosen this topic, because it combines the knowledge I have gained during my master in agroecolgy with the background I have from my bachelor in environment and natural resources.

The green revolution has undeniable increased agricultural yields; however, as an agroecologist I would like to emphasize the need for alternative farming methods, which focus on diversity instead of monoculture. This would also reduce the need for pesticides. Modern agriculture, as it is today, has caused many environmental problems, such as soil degradation, water pollution and the reduction of biodiversity. It is true, that the conversion to alternative and more environmental friendly farming systems is a long-term goal and will not happen overnight, but we should at least aim for it. In the meantime, it is important to reduce the negative impacts towards the environment and human health to the best of our abilities. Here, pesticide risk models seem to have a great potential as preventive measurement against the contamination of our environment. It gives us the possibility to choose plant protection strategies which cause less harm for human health and the environment. That was also another reason why I wanted to learn more about the topic and possibilities interconnected with it.

I would like to thank my supervisors Ole Martin Eklo and Tor Arvid Breland, for their support and guidance throughout the research period. In addition, I would like to thank Matteo Balderacchi and Marco Trevisan, for the supervision during my stay in Italy. I appreciated the kind reception I got.

I am also very thankful to my family and their everlasting support and patience during my studies. I imagine it was not always easy.

Thanks to you all!

Mandy Häger

SUMMARY

The pollution and depletion of our groundwater resources is one of the biggest threats to our society. In recent times, groundwater has been facing an increasing pressure from intensive land use (e.g. agriculture, industry, forestry, etc) and overconsumption by people. In many areas of the world the quantity and quality of groundwater aquifers has been negative affected; causing harm to both humans and the environment.

This paper has been written in connection with the Genesis project, which aims to identify threats to groundwater and groundwater dependent ecosystems, to increase the knowledge in relation to groundwater systems, to develop new tools and indicators for a better groundwater management and to give a new scientific foundation for the revision of the groundwater directive (GWD).

The main focus of this thesis lies on the risk assessment, in relation to groundwater contamination caused by pesticides, under Norwegian conditions. Here, a risk evaluation was undertaken by means of the risk indicator model (EPRIP); and for the area Grue, a small municipality located in the south-eastern part of Norway. Simulations were done for potato and spring wheat production, a total of 9 different soil types and 44 pesticides. Active ingredients were then grouped in (1) risk classes according to the final EPRIP score and (2) risk classes according to predicted environmental concentration in groundwater and hydrological class. The results were so compared with field data and risk classifications obtained by MACRO_GV (for the same area), in order to validate the outcomes and to identify whether EPRIP is suitable for Norwegian conditions or not.

Due to large difference between the predicted environmental concentrations (PEC) in groundwater, achieved by MACRO_GV and EPRIP; calibrations (in relation to water table thickness and water table depth) were undertaken for last named model. This has been done in order to ensure a better foundation for the comparison of the two models, by reason of the different approaches they use for the calculation of the PEC in groundwater. Due to limited time, four active ingredients were chosen in order to monitor the effects of the calibration; those were MCPA, metribuzin, tribenuron-methyl and rimsulfuron. Parameters were adjusted gradually; meaning that simulations were done for (1) a water table thickness of 0.3 m, (2) a water table depth of 1 m, and (3) a change in both parameters simultaneously.

Risk evaluations undertaken for potato and spring wheat production, by means of the risk indicator model (EPRIP), indicated that the agreement, with MACRO_GV and field data, was best when simulations were accomplished with calibrated values. The modification of both parameters simultaneously gave a good consistency between EPRIP and MACRO_GV, in respect to metribuzin and MCPA. In contrast, the agreement for low dose pesticides (rimsulfuron and tribenuron-methyl) was not as good. Risk classification of MCPA and metribuzin were also reflected by findings in the field.

Due to the lack of simulation results, it is difficult to give a clear answer as to whether output values of EPRIP are reliable and as to whether the model is suitable for Norwegian conditions or not. More simulations should be carried out in order to support the findings in this study and to give a more specific answer.

TABLE OF CONTENT

1. INTRODUCTION

The world population is increasing and the need for a reliable food source has become of prime importance. Modern agriculture, with its new technologies and chemical additives has long been praised as a promising solution for a safe food supply. However, it has been shown that intensive farming has negative impacts on human health and the environment. Soil degradation, the loss of biodiversity and wildlife habitats, the use of nonrenewable resources and the pollution of rivers and streams are only few of the outcomes that modern agriculture provides us with. Lately, food safety issues have become of major concern. Food scandals and media reports about pesticide, nitrate and veterinary drug residues in edibles have increased consumer awareness and the demand for environmental friendly and healthy foodstuff.

It is undeniable that pesticides have become an important tool to ensure stable yields within agriculture. However, it is well known that pesticides have negative side-effects on the environment and human health. The book silent spring written by Rachel Carson (1962) clearly describes the hazardous consequences that chemical substances can have on a natural system. Since then, many measurements have been taken in order to minimize the risk associated with the use of pesticides; for instance several directives (e.g. EU water directive (WFD) (EC 2000:60), groundwater directive (GWD) (EC 2006:118), etc.) have been originated and maximum permissible values have been set. Field studies have been undertaken and risk models developed. In recent years, many farmers have started to practice integrated pest management (IPM); a strategy that employs a multiplicity of methods in order to suppress the population of insects, pathogens and weeds beneath an economic threshold value, without damaging the environment. Others again have chosen to abstain from the use of pesticides completely.

In Norway, a national risk reduction plan (Landbruks- og matdepartementet 2009) has been implemented with the aim to minimize the risk for human health and the environment; and to reduce the dependence on plant protection agents within agricultural production. In 2009, an international project called GENESIS (Groundwater and Dependent Ecosystems: New Scientific and Technical Basis for Assessing Climate Change and Land-use Impacts on Groundwater Systems) has been created. It involves 25 organizations from 17 different countries and illustrates that international teamwork has become of significant importance when it comes to today's big challenges. The project has the purpose to *"integrate pre-*

existing and new scientific knowledge into new methods, concepts and tools for the revision of the GWD and better management of groundwater resources" (GENESIS 2008).

The main focus of this paper will lie on the risk assessment of groundwater contamination in relation with pesticide leaching under Norwegian conditions. At this, the environmental potential risk indicator for pesticides (EPRIP) (Balderacchi et al. 2007) was used and applied for the area Grue, a municipality in the south-eastern part of Norway. The results were then compared with another pesticide risk assessment study undertaken in the same area and by means of the one-dimensional model MACRO GV (Stenemo et al. 2005). This was done in order to identify threats to groundwater and groundwater dependent ecosystems (GWDE); and to determine whether EPRIP can be operated as a farmer advising tool under Norwegian conditions. This paper will also examine different aspects of agrochemical use in relation to human health, the environment and agriculture itself; and discuss the potential of alternative methods in order to reduce the environmental impacts connected with the application of pesticides in agriculture.

2. PESTICIDE FATE AND RISK ASSESSMENT

2.1 Trends and facts about pesticide use in Norwegian agriculture

In Norway, agricultural production covers approximately 3 % (Landbruks- og matdepartementet s.a.) of the countries territory , whereupon crop production is located in the south and livestock breeding in the western and more mountainous areas. Organic farming accounts for 4.3 % of the total agricultural area and is expected to increase in the upcoming years (Debio 2009). Compared to other countries, the use of pesticides in Norway is generally low. This is most likely due to the cold climate and the sparse occurrence of agricultural pests. Agrochemicals are approved by the Norwegian food safety authorities (Mattilsynet) and there are strong regulations regarding authorization and use of pesticides. In 2009, the total sales volume related to active ingredient accounted for 581.0 metric tons (Mattilsynet 2010); this is a reduction to previous years, but still somewhat higher than reported in 2005 (figure 1). The low sales in 2005 can be explained by the tax regulations undertaken in 2004; resulting in hoarding of pesticides among importers and distributors the same year. A detailed development for sales regarding herbicides, insecticides and fungicides can be seen in figure 2. In 2008, 96 % of the total potato production area has been treated with pesticides, whereas fungicides and insecticides constituted the biggest part. Approximately 98 % of the total wheat area was sprayed with pesticides in 2008; only 200 of 4200 farm yards with spring wheat production did not apply any agrochemicals on their fields. Pesticide application in wheat is mainly due to problems related to weeds and fungi (Statistics Norway 2009). Figure 3 gives a detailed overview in matter of total area treated with pesticides for different crop production systems. In the last 20-30 years the total use of pesticides in Norway has strongly decreased and it seems that the usage recently has stabilized at a constant level (appendix 1) (Mattilsynet 2010).

Groundwater pollution by pesticides is a big issue related to modern agriculture. Several studies (Gilliom et al. 1999; Ludvigsen et al. 2008; Spliid & Koppen 1998) have indicated that certain pesticides are prone to leaching and hence can contaminate groundwater and other water resources. Gilliom et al (1999) found that 95 % of the samples taken from streams; and nearly 50 % of samples from wells in the US were contaminated with pesticides. Also in Norway pesticide contamination has been detected. The most frequently found pesticides were herbicides, followed by fungicides and insecticides (Haarstad & Ludvigsen 2007). However, concentrations were in most cases low and

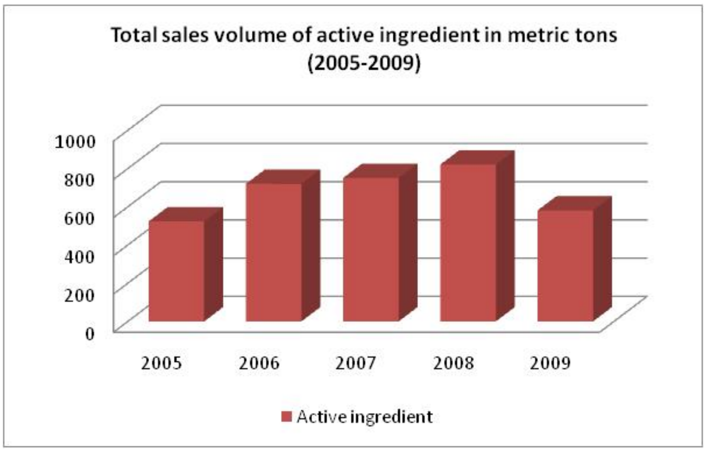


Figure 1: Total sales volume of active ingredient in metric tons (2005-2009). Based on (Mattilsynet 2010)

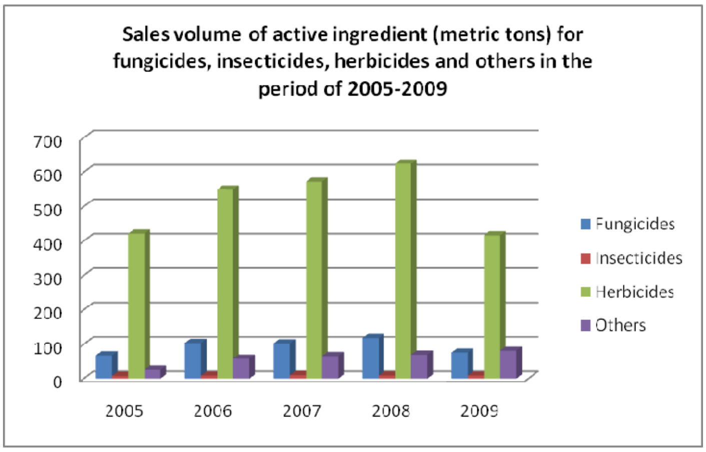


Figure 2: Volume of pesticide sales (metric tons) for respectively fungicides, insecticides, herbicides and others in the period of 2005 – 2009. Based on (Mattilsynet 2010)

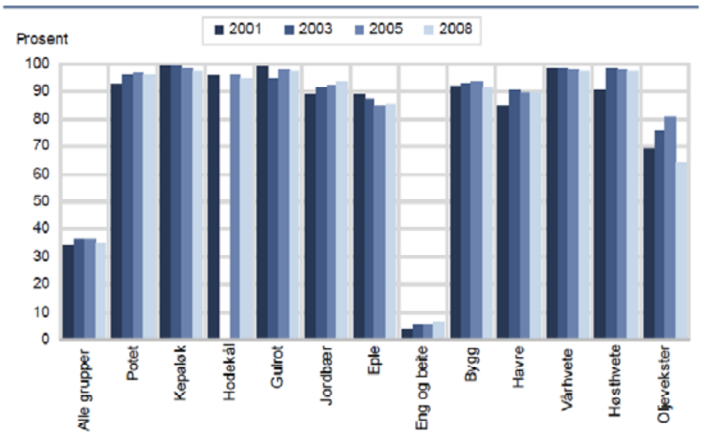


Figure 3: Area treated with pesticides (%) for the years 2001, 2002, 2005 and 2008; , subdivided according to crop production (Statistics Norway 2009)

under the maximum permissible value of 0.1 µg/L (EC 2006:118) . In Norway, a national risk reduction plan has been developed in order to minimize the environmental risk related to pesticide use in agriculture. The plan aims to reduce the dependency of agrochemical substances in Norwegian agriculture and focuses on the implementation of organic- and integrated plant protection methods. Another goal is to increase knowledge among end-users in order to assure correct pesticide applications on agricultural land (Landbruks- og matdepartementet 2009).

2.2 Environmental behavior of pesticides in soil

When entering the agrosystem, pesticides are affected by many processes; influencing their environmental fate (figure 4). Sometimes, these processes can be beneficial by moving the pesticide to the target area; other times they can be unfavorable by causing environmental damage and crop injury (Fishel 1997). In order to avoid negative impacts towards the environment and agricultural production it is necessary to understand the environmental behavior of pesticides. There are three main processes affecting the environmental fate of pesticides within an agrosystem; adsorption, transport and degradation. These processes are in turn influenced by factors like climate, agricultural practice and soil type.

(1) Adsorption

Adsorption is a process that binds agrochemical compounds to soil particles, thereby reducing bioavailability, mobility, degradation and transport of pesticides. Soil adsorption mechanisms occur by Van der Waals force, hydrogen bonding, covalent bonding and ion exchange, depending on the soil type and the chemical properties of the pesticide (Shiyomi & Koizumi 2001). Non-ionic pesticides are mainly adsorbed to organic matter, whereas ionic pesticides are adsorbed to clay and iron oxides (Arias-Estevez et al. 2008). This means that soils with high organic matter and clay content are less prone to leaching than soils with a sandy texture and low organic matter content. Adsorption can interfere with the pest control strategies by reducing the effect of agrochemicals, resulting in higher application rates.

(2) Transport

In the following section, pesticide transport will be described; focusing mainly on factors affecting pesticides leaching to groundwater. Pesticides transport encompasses spray drift, votalization, runoff, crop removal and leaching. **Spray drift** is the amount of pesticide transported away from the treatment site during application. The degree of spray drift is affected by; droplet size, wind speed and distance between crop and application tool (Ministry of Agriculture and Lands s.a.). Volatilization is the conversion from a solid or liquid phase to a gaseous phase, and hence associated with the loss of pesticides to the atmosphere. The vapor pressure greatly influences the volatilization potential, meaning the greater the vapor pressure the greater the amount lost to the atmosphere (Fishel 1997). Factors, such as high temperature, low humidity and air movement tend to increase votalization. Pesticide **runoff** is often related to the pollution of surface water from agricultural land. Transport occurs by either direct mixing with water or by soil erosion. Runoff is governed by many factors; e.g. slope, precipitation, agrochemical properties and soil type.

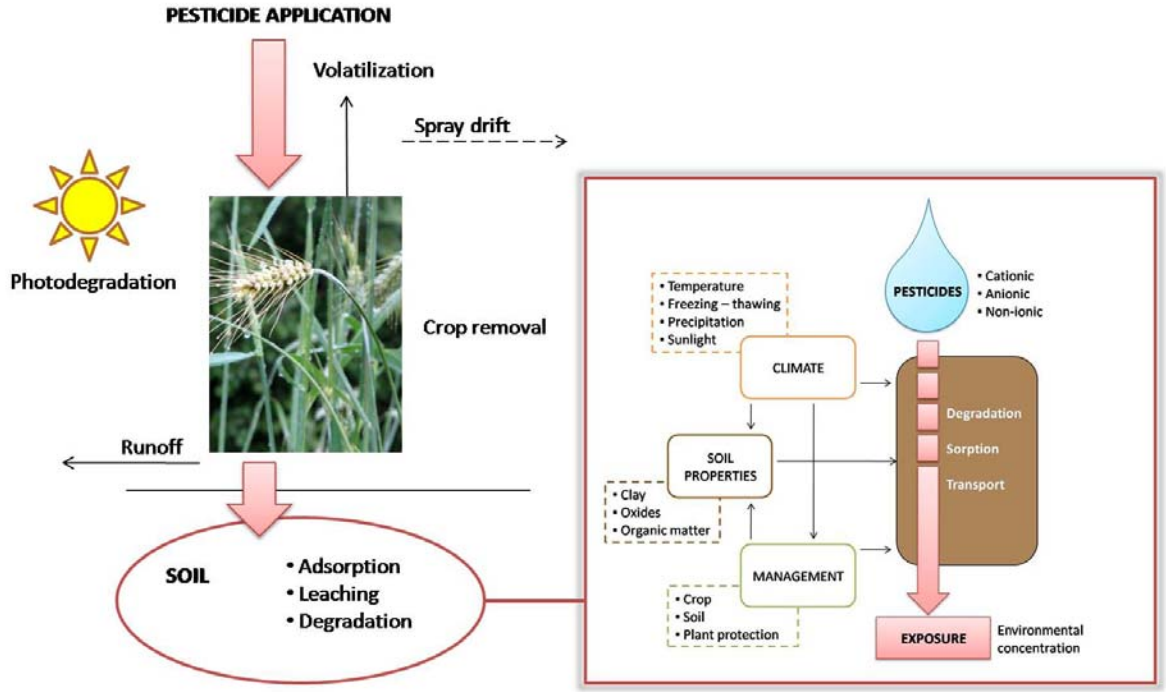


Figure 4: Environmental fate of pesticides. Based on (Fishel 1997; Ministry of Agriculture and Lands s.a.) and Eklo O.M.

Pesticide **leaching** to groundwater is governed by many factors, e.g. soil properties, hydrogeological structure, climatic parameters, agricultural methods, chemical properties of the pesticide, etc (Roberts & Kearney 1995). The leaching potential is greatly influenced by two key factors; mobility and persistence. Mobility is affected by the degree of adsorption and hence governed by soil characterization and chemical properties of the pesticide. In addition, it has been revealed that agricultural methods have a huge impact on the mobility of pesticides in the soil. The application rate, the application method and the timing of the application are important factors related to pesticide leaching. Direct soil incorporation before planting seems to increase the leaching potential. Foliage application on the other hand tends to reduce the risk (Roberts & Kearney 1995). Further, tillage operations appear to influence the persistence of agrochemicals in the soil. No tillage or minimum tillage after application tends to leave higher concentrations of pesticides in the soil (Curran 1998). This might be especially negative since systems with no or minimum tillage often seem to have an increased occurrence of weeds and hence a higher application of pesticides.

Persistence is the lengths of time a pesticide remains active in soil. Chemical properties such as water solubility, half life, vapor pressure and the vulnerability to chemical or microbial degradation can provide us with a rough estimate about environmental persistence (Curran 1998). Soil structure and pH are other important factors influencing persistence in the soil.

(3) Degradation

Pesticide degradation can be distinguished between biological degradation (by soil organisms) and non-biological degradation (chemical and photolysis). Usually, degradation results in the formation of less toxic compounds. However, for some pesticides the degradation metabolites can be more toxic than the original compound (Shiyomi & Koizumi 2001). There are several factors affecting degradation, whereas climatic parameters seem among the most important ones. Areas with warm climate, for instance, have a faster microbial degradation than areas with cold and moist climate; indicating a lower leaching potential in warmer areas (Roberts & Kearney 1995). Soil pH and moisture are other factors influencing soil degradation.

2.3 Pesticide risk indicator models

In recent years, many different kinds of risk assessment models have been developed in order to monitor and evaluate the risk of pesticides towards human health and the environment. A model can be defined as a simple specification of a given part of reality (Balderacchi et al. 2007). An ideal risk indicator should meet the following requirements (Centre for Agriculture and Environment (CLM) 1999; Dubus & Surdyk 2006): (1) the model should be user-friendly and easy to understand, (2) it should have a good theoretical foundation, (3) be appropriate to scale, (4) it should aim to balance the issue of complexity and applicability and (5) it should produce reliable information. Here, validation can be achieved by comparing simulation results with field data, making calculations more transparent and evaluating the outcomes by experts.

Methodology

Pesticide risk indicators vary greatly in their methodology, input value and output. A single environmental parameter, for instance, can be used in order to classify pesticides according to their environmental risk. This method can be useful for the determination of pesticide mobility in soil. However, this method does not take into considerations site specific situations and is hence unsuitable for the evaluation of complex farming systems. Another risk assessment method is the use of the environmental impact index. This index is based on the ratio between predicted environmental concentration (PEC) and the predicted no effect concentration (PNEC) (Levitan 1997). A value greater than 1 indicates high environmental risk. The Environmental Impact Quotient (EIQ) is a numerical model developed by Kovach et al. (1992) and considers three compartments of the agroecosystem; the farmer, the consumers and the environment (Walker et al. 1997). The model is based on the formula; Risk = Toxicity x Exposure. Pesticides are so given a score based on the overall estimation of all three compartments. Process based models require in general more complex and detailed input-data. In addition, they can handle site specific situations and provide either environmental scores or/and calculated values in matter of environmental predicted concentrations. However, the more complex the situation is, the more difficult the model gets; making the model user-unfriendly.

Application

Risk assessment models can be classified after their purpose, their application area and target audience. They are amongst others applied as (Levitan 2000):

(1) Research models and political decision tools
(2) Advisory tool for farmers
(3) System for "Green labeling"

Research models and political decision tools have the aim to increase knowledge, monitor pesticide use and to evaluate potential risks associated with the application of pesticides. These models require often huge amounts of data and are narrowed down to a certain field of interest. However, they often do not consider field specific details and are therefore unsuitable as a decision tool at the farm level (Levitan 2000). In contrast, models with the aim to advice farmers about agricultural practice are often more complex, because the farmer has to consider many different aspects of the farming system in order to make the right management decision. Here, the challenge is it to develop field tools that can both integrate detailed and variable data, and at the same time ensure an easy handling of the model. The object of green labeling is it to provide consumers with information regarding production process and environmental impact; and to motivate them to buy a certain product. The typical approach for the ecolabels is a checklist, which indicates whether standards have been met or not. Here, site specific values are not considered, which might create a wrong picture for consumer.

Practical use in Norway

In Norway, there have been developed two types of pesticide risk indicators, the environmental risk indicator and the human health risk indicator. These indicators have been designed in order to classify agrochemicals according to risk classes, to monitor the risk of pesticide use in agriculture, to evaluate the risk of newly developed pesticides and to calculate green taxes. In order to estimate the risk for human health one has to consider the chemical properties of the pesticide and the human exposure related to mixing and spreading. Each field is given a risk point. The total exposure rate is calculated by multiplying the risk points associated with pesticide mixing and spreading. The total health risk is so evaluated by multiplying the total exposure rate with the risk points, based on the health hazard composed by the pesticide itself. Altogether, there are three health risk classes; low (< 8), medium (8 – 16) and high (>16) (Spikkerud et al. 2005). The environmental risk is calculated by summing the environmental risk for earthworms, the environmental risk for bees and beneficial organisms, the environmental risk for birds, the leaching potential, persistence, bioaccumulation and type of formulation; which is related to the risk of spill during mixing. The risk is grouped into three risk classes, low (< 4), medium (4-8) and high (>8). For detailed information on how to calculate the different compartments q.v. Spikkerud et al 2005.

Advantages and disadvantages

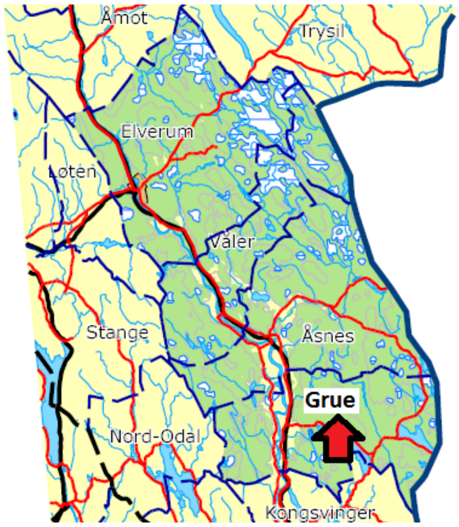
The application of computer models for the assessment of environmental and human risk has several advantages over the accomplishment of field studies. First of all they are less time consuming and expensive than field experiments. In addition they are more flexible and can be applied in a wide context. On the other hand, computer models often require large sets of data, which can be difficult to obtain. Another problem is the matter of complexity; the more complex a system is the more difficult a model gets. This often sets limits to the ease of use and hence the number of users. The assessment of reliability and accuracy is another major problem (Roberts & Kearney 1995). A model can never give an absolute answer, due to the many variations of the environment. However, it can provide us with a rough estimate; that can be useful as a supportive tool in decision making processes. Therefore, one should keep in mind that pesticide risk assessment models should not be used separately, but as a part of a holistic systems approach.

3. MATERIALS AND METHOD

3.1 The research area

By means of the environmental potential risk indicator for pesticides (EPRIP), a risk assessment has been carried out for the area Grue (N 60 28 E 12 02); a small municipality located in the county Hedmark, in the south-eastern part of Norway. The area is dominated by forestry and intensive agriculture with mostly potato and cereal production. Here, along forested hills, curls the biggest river of Norway; Glomma. With only a few exceptions, the area is mostly covered by permeable soils.

In 1996, pesticide concentrations were detected in groundwater wells, allocated near agricultural fields; indicating that the area might be vulnerable to leaching (Eklo et al. 2002). Detected pesticides were ETU, metribuzin, and metalaksyl; and all findings exceeded the maximum permissible value for drinking water (EC 2006:118). Based on the results of the study, the area was chosen for further investigations. Diffuse pesticide leaching simulations were undertaken and risk maps developed in order to help farmers to prevent the contamination of groundwater and farm wells.



Figur 5: Geographical location of Grue. (©Geovekst and Statens kartverk)

Figure 6: Reseach area at Grue. Photo: Randi Bolli

3.1.1 Climatic parameters

The area of research is characterized by a relatively dry climate with low precipitation. Annual precipitation in the region is approximately 635 mm whereas most precipitation occurs in the period June-October. Maximum rainfall per day is estimated to be 36.08 mm. This number was obtained by calculating the average for the highest precipitation value of each year, in the period 1989-2004. The average annual temperature is 3.3 ^{o}C, with a minimum normal mean temperature of -7.4 ^{o}C and a maximum normal mean temperature of 15.3 ^{o}C. The climate data was obtained from the Norwegian meteorological institute (http://eklima.met.no); weather station 5650- Vinger.

3.1.2 Soil types and parameters

Grue is located above a profound basin filled with marine deposits and a top layer of fluvial sediments (Eklo et al. s.a.). The region is covered by mainly permeable soils, with some few exceptions of low permeable ones. Clay was found within a depth of 13-15 meter. Above this level the deposit is mainly characterize by silt and sand. The fluvial deposits in this area are relatively young and displayed by a fine-grained top layer and a coarser layer below (Eklo et al. 2002). The dominating soil type in the region is Galterud sandy loam (KGl5), whereas the top layer consists of approximately 31% sand, 63% silt and 6% clay. Organic carbon content is estimated to 1-2 %. The Norwegian institute for forest and landscape (Skog og landskap) has investigated and mapped the area. Soil properties and profile description for the nine soil types, used in this study, can be seen in appendix 2.

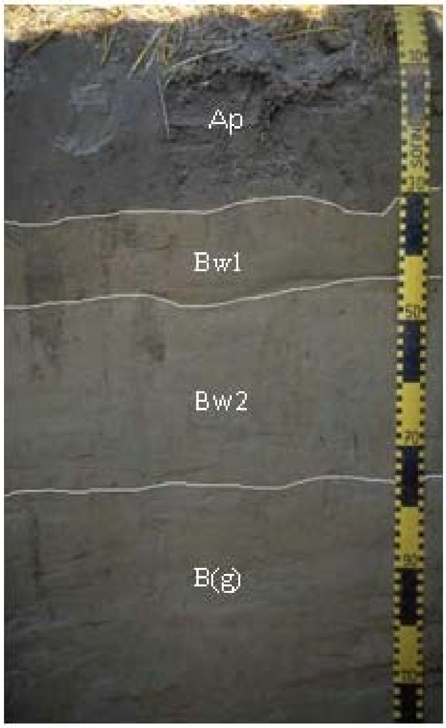


Figure 7: Soil profile for Galterud sandy loam (KGl5). Photo: Eivind Solbakken

The bulk density for the soil types were calculated by means of the soil parameter estimate (Soilpar 2) (Acutis & Donatelli 2003). The obtained values were controlled and affirmed by the institute of forest and landscape. Soil type classification in relation to hydrological class can be seen in table 1.

Table 1: Soil classification in matter of hydrological class, based on (Eklo et al. 2009)

Series	Hydrological class	Description	
ATm4	A	Hydrological class A :	Well drained soil with no drains or or no gley features within 100 cm depth .
AFs5	B		
FOs5	B		
TLt5	B	Hydrological class B:	Moderately well drained soils with glay features within 100 cm depth and poorly drained soils with gley features directly below the topsoil or soils that have drains
KMk5	B		
KGl5	A		
KLr5	B		
TKi5	B	Hydrological class C:	Poorly drained soils formed on massive clays or shallow soils on hard rocks.
THg5	B		

3.1.3 Groundwater

The groundwater in the area around Grue is mainly used for drinking water purposes and irrigation. Groundwater recharge has been estimated to 0.3 m year^{-1}. The water table depth has a value of 3.75 m (Eklo et al. s.a.), but can vary considerably depending on factors like precipitation, snow melting etc. Clay has been found within a depth of approximately 13-15 m; the water table thickness has therefore been set to 10 m. The hydraulic gradient was 0.2 %. The river Glomma is supplied with water from the groundwater aquifer and only under flood tides water from Glomma can reach the aquifer. Many of the agricultural fields in the area are closely located to the river; however, the risk of pesticide contamination is assumed to be low due to dilution. In this study, the small pond Gruetjern has been selected as research object in order to simulate the environmental effect of pesticides on groundwater depending ecosystems. The pond has a width of approximately 25 m and a depth of 2 m. The distance to agricultural fields is 10 m.

3.2 Previous investigations with the model MACRO_GV

By means of the model MACRO_GV, there has been carried out a risk assessment study in connection with diffuse pesticide leaching to groundwater aquifers, for the area Grue. MACRO_GV is a one-dimensional, mechanistic model, that simulates the transport and fate of agricultural pesticides (Stenemo et al. 2007). A mechanistic model applies current scientific knowledge in order to incorporate the most fundamental descriptions of an important or relevant process. It addresses a high number of aspects for each simulation process (Balderacchi et al. 2007; Roberts & Kearney 1995). Within MACRO_GV, the soil component is divided into two sections, the micropore and the macropore section. For parameterization the model employs easily available parameters, such as soil texture and organic matter content (Eklo et al. 2009). MACRO_GV is linked to a database, consisting of climate and pesticide values. The end-user so defines the climatic conditions, the crop, the soil texture, the organic matter content, the active ingredient and the treatment. Pesticide leaching is simulated for a depth of 1m and a period of 26 years, whereas the first six years are not included in the calculation process. The results of the simulation are represented as an annual mean concentration (µg/L) and an average concentration (µg/L) of the last 20 years; a safety coefficient is also included (Stenemo et al. 2005).

The risk assessment was carried out for nine soil types and 44 agrochemicals. Simulations were done for both potato and grain production. The pesticides were grouped in risk classes (no/ low/ moderate and high risk) according to hydrological class and the simulated mean concentration at 1m depth (µg/L). The study clearly demonstrated that herbicides compose a great risk in regard to leaching (Eklo et al. 2009). The risk for groundwater contamination by fungicides and insecticides were relatively low. It has also been indicated that grain production constitutes a higher leaching potential than potato production; for detailed information about the results, see appendix 3. A risk analysis undertaken with MACRO_DB illustrated good agreement between simulated pesticide concentrations and samples taken in the field (Eklo et al. 2002). Based on the results, obtained by MACRO_GV, risk maps have been developed in order to provide farmers with information on how to prevent leaching of pesticides to groundwater.

3.3 The EPRIP-model

The risk indicator EPRIP has been developed in order to provide farmers with a decision tool in order to select the most suitable and environmental friendly agrochemical for their farming system (Trevisan et al. 2009). EPRIP is considered a good advisory tool for farmers due to its user-friendly profile and easily available input-parameters. The model determines the predicted environmental concentration, for four compartments; groundwater, surface water (drift and run-off), air and soil (Balderacchi et al. 2007). The potential risk index (ETR) is estimated by dividing the respective PEC with a toxicological parameter that reflects the risk for non-target organisms, living in the specific environmental compartment. The non-target organisms for surface water were *Daphnia Magna*, fish and algae. Toxicity related to air exposure was estimated by the usage of LC_{50} values for rats (inhalation). Earthworms were selected as non-target organisms for soil. The toxicity related to groundwater contamination was linked to drinking water standards (0,1 µg/L) (Balderacchi et al. 2007).Altogether, nine ETR values are calculated; one for groundwater, one for soil, one for air; and six for surface water. ETR values are so converted into risk points, applying a scale from 1-5 (Balderacchi et al. 2007). The final EPRIP score is obtained by multiplying the risk points for the different compartments.

EPRIP is divided into four main sections; database, scenario, application and judgment. The database consists of information regarding: active ingredient, soil, climate, water body and crop. Here, pre-existing data can be modified or new data added. The scenario requires data concerning: organic carbon content, water body distance, perimeter, area, soil type, water body, crop and climate. In the third part (application of the agrochemical) the active ingredient is added to the simulation. Information regarding dosage, incorporation depth, number of applications, interval and the phenological state is required. The results of the risk assessment are represented in the section "judgment". Output data is obtained in form of risk points and intermediate values for each environmental compartment and the final EPRIP score. In this study, the main focus was turned towards the predicted environmental concentration for groundwater, which was obtained by the following formula:

$$(1)\ LQ = \frac{2.739 * \mathrm{AF} * \mathrm{RATE} * (1-\mathrm{f}int) * (1-\mathrm{f}drift)}{\mathrm{P} * \mathrm{H}}$$

Rate	= Application dose	F*drift*	= Drift loss
H	= Height of water table layer	AF	= Attenuation factor
F*int*	= Quantity intercepted by the crop	P	= Soil porosity

For further description of the model, q.v. Trevisan et al. (2009) and Balderacchi et al (2007)

3.4 Procedure

In this study, a risk assessment was carried out for a total of 9 different soil types and 44 pesticides. Simulations were conducted for both potato and spring wheat production. Data regarding soil parameters (texture, bulk density, slope and water table[1]), climate, and agricultural treatment, organic carbon content, field perimeter, field area, plant production and water body were required. Soil parameters were obtained from the Norwegian institute for forest and landscape, with the exception of bulk density, which was calculated by means of SoiPar2. The climatic parameters were gained from the Norwegian meteorological institute. Application data, such as NAD, application time, interval and number of applications was provided by Bioforsk and Statistics Norway. The dose of application was obtained by multiplying the amount of the active ingredient with the application dosage of the product (NAD). Updates in relation to the agrochemical database of EPRIP were accomplished by consulting the pesticide database of footprint (http://www.eu-footprint.org/), a webpage side founded by the European commission. Detailed information about input data is given in attachment 4.

The risk assessment was carried out by means of the pesticides risk indicator model EPRIP. Active ingredients were then grouped in (1) risk classes according to the final EPRIP score and (2) risk classes according to predicted environmental concentration in groundwater and hydrological class. The outcomes were so compared with field data and risk classifications in relation to MACRO_GV.

Table 1: Risk classification scheme based on hydrological class and predicted environmental concentration in groundwater

	Konsentrasjoner (µg/L) simulert med MACRO_GV				
Hydrologisk klasse	< 0.001	0.001 - 0.01	0.01 - 0.1	0.1 - 1	> 1
A	1	2	3	4	4
B	1	1	2	3	4
C	1	1	1	1	1

3.4.1 Model calibrations

Due to large differences in output values between EPRIP and MACRO_GV during the first simulation round, calibrations have been undertaken for the model EPRIP. Here, water table depth was reduced from 3.75 m to 1 m; and water table thickness from 10 m to 0.3 m. This has been done for the reason that MACRO_GV only simulates the predicted environmental concentration down to 1 m and considers the annual recharge, instead of the water table

[1] In EPRIP, the water table is constituted of water table thickness, water table depth and water table recharge.

thickness. In this way a better foundation for the comparison of EPRIP and MACRO_GV was obtained.

Due to limited time, four plant protection agents were chosen to monitor the effect of the calibrations. Sencor and Titus were selected for potato production and Express and MCPA 750 for spring wheat production. Parameters were adjusted gradually; meaning that simulations were done for (1) a water table thickness of 0.3 m, (2) a water table depth of 1 m, and (3) a change in both parameters simultaneously. In order to estimate whether maximum daily rainfall has an impact on the results, the value was changed from 36.1 mm to 85.0 mm; representing the highest daily precipitation value in the period 1989-2004. Here, simulations were carried out for (a) an unaltered situation and (b) a situation with altered water table depth and water table thickness.

4. RESULTS

4.1 Simulations and calibrations

The final EPRIP score, in matter of the environmental compartments: air, soil, ground- and surface water; indicated no risk for almost all active ingredients, used in potato and spring wheat production in Grue. The only exception was esfenvalerate, which had an EPRIP score that resulted in the estimation of a small environmental risk (appendix 5). Model calibrations were not undertaken for this simulation.

4.1.1 Potato production

Table 3: Risk classification of pesticides, used in potato production, according to predicted environmental concentration in groundwater and hydrological class. Grue. Water table thickness: 10 m and water table depth 3.75 m.

Merchandise	Active ingredient	ATm4	AFs5	FOs5	TLt5	KMk5	KGl5	KLr5	TKi5	THg5	Dose (NAD)
Rizolex 50 FW	Tolclofos methyl	1	1	1	1	1	1	1	1	1	75 ml/daa
Fenix	Aclonifen	1	1	1	1	1	1	1	1	1	175 ml/daa
Finale	Glufosinate -ammonium	3	2	1	1	2	3	2	2	2	500 ml/daa
Focus Ultra	Cycloxydim	1	1	1	1	1	1	1	1	1	600 ml/daa
Select	Clethodim	1	1	1	1	1	1	1	1	1	50 ml/daa
Sencor	Metribuzin	2	1	1	1	1	2	1	1	1	30 g/daa
Titus	Rimsulfuron	1	1	1	1	1	1	1	1	1	5 g/daa
Acrobat WG	Dimetomorph	2	1	1	1	1	2	1	1	1	200 g/daa
	Mancozeb	1	1	1	1	1	1	1	1	1	
Dithane NewTec	Mancozeb	1	1	1	1	1	1	1	1	1	200 g/daa
Electis	Zoxamide	1	1	1	1	1	1	1	1	1	180 g/daa
	Mancozeb	1	1	1	1	1	1	1	1	1	
Sereno WG	Fenamidone	1	1	1	1	1	1	1	1	1	125 g/daa
	Mancozeb	1	1	1	1	1	1	1	1	1	
Shirlan	Fluazinam	1	1	1	1	1	1	1	1	1	40 ml/daa
Tattoo	Propamocarb	2	1	1	1	1	2	1	1	1	400 ml/daa
	Mancozeb	1	1	1	1	1	1	1	1	1	
Fastac 50	Alpha-cypermethrin	1	1	1	1	1	1	1	1	1	40 ml/daa
Karate 2.5 WG	Lambda-cyhalothrin	1	1	1	1	1	1	1	1	1	80 g/daa
Sumi-Alpha	Esfenvalerate	1	1	1	1	1	1	1	1	1	30 ml/daa
Reglone	Diquat dibromide	1	1	1	1	1	1	1	1	1	300 ml/daa

1 = no risk
2 = low risk
3 = moderate risk
4 = high risk

Simulation round no. 1, gave an estimate of primary no risk for groundwater contamination in relation to pesticide application in potato production, for the area Grue (table 3). However, the model indicated that soils grouped in hydrological class A (ATm4 and KGl5), are more vulnerable to pesticide leaching than the other soils, analysed in this study. Soils in hydrological class A are of well drained characted and often low in organic mattter content. Glufosinate-ammonium had a somewhat higher score than the other active ingredients

Table 4: Risk classification of pesticides, used in potato production, according to predicted environmental concentration in groundwater and hydrological class. Grue Water table thickness = 0.3 m and water table depth = 3.75 m.

Merchandise	Active ingredient		ATm4	AFs5	FOs5	TLt5	KMk5	KGl5	KLr5	TKi5	THg5
		PEC -Groundwater (µg/L)									
Sencor	Metribuzin		1,25E-01	7,46E-02	3,87E-02	1,52E-02	7,29E-02	1,19E-01	7,46E-02	7,50E-02	7,35E-02
		Risk	4	2	2	2	2	4	2	2	2
Titus	Rimsulfuron		6,05E-03	4,46E-03	3,00E-03	1,81E-03	4,56E-03	5,99E-03	4,46E-03	4,49E-03	4,32E-03
		Risk	2	1	1	1	1	2	1	1	1

Table 5: Risk classification of pesticides, used in potato production, according to predicted environmental concentration in groundwater and hydrological class. Grue Water table thickness = 10 m, water table depth: 1 m.

Merchandise	Active ingredient		ATm4	AFs5	FOs5	TLt5	KMk5	KGl5	KLr5	TKi5	THg5
		PEC -Groundwater (µg/L)									
Sencor	Metribuzin		6,53E-03	5,55E-03	4,47E-03	3,66E-03	5,83E-03	6,60E-03	5,55E-03	5,59E-03	5,31E-03
		Risk	2	1	1	1	1	2	1	1	1
Titus	Rimsulfuron		2,48E-04	2,23E-04	1,93E-04	1,76E-04	2,37E-04	2,53E-04	2,23E-04	2,25E-04	2,12E-04
		Risk	1	1	1	1	1	1	1	1	1

Table 6: Risk classification of pesticides, used in potato production, according to predicted environmental concentration in groundwater and hydrological class. Grue. Water table thickness = 0.3 m and water table depth: 1m

Merchandise	Active ingredient		ATm4	AFs5	FOs5	TLt5	KMk5	KGl5	KLr5	TKi5	THg5
		PEC -Groundwater (µg/L)									
Sencor	Metribuzin		2,18E-01	1,85E-01	1,49E-01	1,22E-01	1,94E-01	2,20E-01	1,85E-01	1,86E-01	1,77E-01
		Risk	4	3	3	3	3	4	3	3	3
Titus	Rimsulfuron		8,26E-03	7,43E-03	6,42E-03	5,88E-03	7,90E-03	8,45E-03	7,43E-03	7,49E-03	7,08E-03
		Risk	2	1	1	1	1	2	1	1	1

1 = no risk
2 = low risk
3 = moderate risk
4 = high risk

Table 7: Overall evaluation of all environmental compartments (air, groundwater, soil and surface water) in relation to pesticide application in potato production. Grue. Water table thickness = 0.3 m, water table depth = 1m.

Merchandise	Active ingredient		ATm4	AFs5	FOs5	TLt5	KMk5	KGl5	KLr5	TKi5	THg5
Sencor	Metribuzin		2	2	2	2	2	2	2	2	2
Titus	Rimsulfuron		1	1	1	1	1	1	1	1	1

EPRIP score	EPRIP judgement	EPRIP judgement (value)
1	No	0
2-16	Negligible	1
17-81	Small	2
82-256	Present	3
257-400	Large	4
>400	Very large	5

A reduction of the water table thickness from 10m to 0.3m, resulted in a higher risk classification (table 4), than obtained for previous simulations (table 3). Changes were in particular visible for metribuzin, where risk classes strongly differed from classifications obtained before. In contrast, only few changes were observed for rimsulfuron. Here, the risk for groundwater contamination increased slightly for soils grouped in hydrological class A (ATm4, KGl5). The modifications undertaken for water table depth resulted in only small changes for the predicted environmental concentration in groundwater and were not noticeable in matter of risk classes (table 5). The simultaneous alteration of both parameters (water table depth and water table thickness) was followed by visible changes for both metribuzin and rimsulfuron (table 6). Also here, changes were more noticeable for metribuzin than for rimsulfuron. In addition, calibrations resulted in a better agreement in relation to MACRO_GV. However, this was basically only obtained for metribuzin. The risk of pesticide leaching to groundwater was more prevail in soils grouped in hydrological class A. The overall evaluation of EPRIP indicated a small environmental risk for metribuzin and no risk for rimsulfuron (table 7).

Calibrations undertaken for maximum daily rainfall did not have an effect on the simulation results (appendix 5).

4.1.2 Spring wheat production

Table 8: Risk classification of pesticides, used in spring wheat production, according to predicted environmental concentration in groundwater and hydrological class. Grue. Water table thickness: 10 m and water table depth 3.75 m.

Merchandise	Active ingredient	ATm4	AFs5	FOs5	TLt5	KMk5	KGl5	KLr5	TKi5	THg5	Dose (NAD)
Actril 3-D	Ioxynil	1	1	1	1	1	1	1	1	1	300 ml/daa
	Dichlorprop - p	2	1	1	1	1	2	1	1	1	
	MCPA	2	1	1	1	1	2	1	1	1	
Ally 50 ST	Metsulfuron - methyl	1	1	1	1	1	1	1	1	1	1.2 g/daa
Ally Class 50 WG	Metsulfuron - methyl	1	1	1	1	1	1	1	1	1	5 g/daa
	Carfentrazone - ethyl	1	1	1	1	1	1	1	1	1	
Ariane S	Fluroxypyr-meptyl	1	1	1	1	1	1	1	1	1	250 ml/daa
	Clopyralid	2	1	1	1	1	2	1	1	1	
	MCPA	2	1	1	1	1	2	1	1	1	
Roundup ECO	Glyphosate	1	1	1	1	1	1	1	1	1	400 ml/daa
Express	Tribenuron - methyl	1	1	1	1	1	1	1	1	1	1 tabl./5 daa
Harmony Plus 50 T	Thifensulfuron - methyl	1	1	1	1	1	1	1	1	1	1.5 g/daa
	Tribenuron - methyl	1	1	1	1	1	1	1	1	1	
Hussar	Mefenpyr - diethyl	1	1	1	1	1	1	1	1	1	20 g/daa
	Iodosulfuron	1	1	1	1	1	1	1	1	1	
MCPA 750	MCPA	3	2	1	1	2	3	2	2	2	400 ml/daa
Optica Mekoprop - P	Mecoprop - p	3	2	1	1	2	3	2	2	2	300 ml/daa
Primus	Florasulam	1	1	1	1	1	1	1	1	1	10 ml/daa
Puma Extra	Fenoxaprop - p - ethyl	1	1	1	1	1	1	1	1	1	120 ml/daa
	Mefenpyr - diethyl	1	1	1	1	1	1	1	1	1	
Starane	Fluroxypyr-meptyl	1	1	1	1	1	1	1	1	1	200 ml/daa
Acanto Prima	Cyprodinil	1	1	1	1	1	1	1	1	1	150 g/daa
	Picoxystrobin	1	1	1	1	1	1	1	1	1	
Amistar	Azoxystrobin	2	1	1	1	1	2	1	1	1	100 ml/daa
Amistar Duo	Azoxystrobin	2	1	1	1	1	2	1	1	1	100 ml/daa
	Propiconazole	2	1	1	1	1	2	1	1	1	
Merchandise	**Active ingredient**	**ATm4**	**AFs5**	**FOs5**	**TLt5**	**KMk5**	**KGl5**	**KLr5**	**TKi5**	**THg5**	**Dose (NAD)**
Amistar Pro	Azoxystrobin	2	1	1	1	1	2	1	1	1	200 ml/daa
	Fenpropimorph	1	1	1	1	1	1	1	1	1	
Comet	Pyraclostrobin	1	1	1	1	1	1	1	1	1	100 ml/daa
Comet Plus	Fenpropimorph	1	1	1	1	1	1	1	1	1	200 ml/daa
	Pyraclostrobin	1	1	1	1	1	1	1	1	1	
Forbel	Fenpropimorph	1	1	1	1	1	1	1	1	1	100 ml/daa
Mentor	Fenpropimorph	1	1	1	1	1	1	1	1	1	50 ml/daa
	Kresoxim-methyl	1	1	1	1	1	1	1	1	1	
Stereo 312.5 EC	Propiconazole	2	1	1	1	1	2	1	1	1	150 ml/daa
	Cyprodinil	1	1	1	1	1	1	1	1	1	
Stratego 250 EC	Propiconazole	2	1	1	1	1	2	1	1	1	100 ml/daa
	Trifloxystrobin	1	1	1	1	1	1	1	1	1	
Stratego 312.5 EC	Propiconazole	1	1	1	1	1	1	1	1	1	100 ml/daa
	Trifloxystrobin	1	1	1	1	1	1	1	1	1	
Zenit 575 EC	Fenpropidin	1	1	1	1	1	1	1	1	1	100 ml/daa
	Propiconazole	1	1	1	1	1	1	1	1	1	
Fastac 50	Alpha cypermethrin	1	1	1	1	1	1	1	1	1	40 ml/daa
Karate 2.5 WG	Lambda - cyhalothrin	1	1	1	1	1	1	1	1	1	80 g/daa
Perfekthion 500 S	Dimethoate	1	1	1	1	1	1	1	1	1	80 ml/daa
Pirimor	Pirimicarb	2	1	1	1	1	2	1	1	1	50 g/daa
Sumi Alpha	Esfenvalerate	1	1	1	1	1	1	1	1	1	30 ml/daa

1 = no risk
2 = low risk
3 = moderate risk
4 = high risk

Simulations undertaken with unmodified values, in relation to water table depth and water table thickness, gave an estimate of primary no risk for groundwater contamination in respect to pesticide application in spring wheat production, for the area Grue (table 8). However, it was indicated that soils grouped in hydrological class A (ATm4 and KGl5), are more vulnerable to pesticide leaching than the other soils, analysed in this study. Soils in hydrological class A are of well drained characted and often low in organic mattter content. MCPA (MCPA 750) and mecoprop-p had a somewhat higher score than the other compounds used in spring wheat production. Compared to potato production, spring wheat production seems to be more vulnerable to pesticide leaching.

Table 9: Risk classification of pesticides, used in spring wheat production, according to predicted environmental concentration in groundwater and hydrological class. Grue. Water table thickness = 0.3 m and water table depth: 3.75 m

Merchandise	Active ingredient		ATm4	AFs5	FOs5	TLt5	KMk5	KGl5	KLr5	TKi5	THg5
		PEC -Groundwater (µg/L)									
Express	Tribenuron-methyl		4,92E-03	3,39E-03	2,12E-03	1,14E-03	3,40E-03	4,75E-03	3,39E-03	3,41E-03	3,29E-03
		Risk	2	1	1	1	1	2	1	1	1
MCPA 750	MCPA		1,18E+00	5,94E-01	2,41E-01	6,18E-02	5,67E-01	1,13E+00	5,95E-01	5,95E-01	6,02E-01
		Risk	4	3	3	2	3	4	3	3	3

Table 10: Risk classification of pesticides, used in spring wheat production, according to predicted environmental concentration in groundwater and hydrological class. Grue. Water table thickness = 10 m and water table depth: 1.0 m)

Merchandise	Active ingredient		ATm4	AFs5	FOs5	TLt5	KMk5	KGl5	KLr5	TKi5	THg5
		PEC -Groundwater (µg/L)									
Express	Tribenuron-methyl		2,17E-04	1,92E-04	1,62E-04	1,44E-04	2,03E-04	2,20E-04	1,92E-04	1,93E-04	1,83E-04
		Risk	1	1	1	1	1	1	1	1	1
MCPA 750	MCPA		7,58E-02	6,16E-02	4,65E-02	3,39E-02	6,43E-02	7,68E-02	6,16E-02	6,20E-02	5,93E-02
		Risk	3	2	2	2	2	3	2	2	2

Table 11: Risk classification of pesticides, used in spring wheat production, according to predicted environmental concentration in groundwater and hydrological class. Grue. Water table thickness = 0.3 m and water table depth = 1 m)

Merchandise	Active ingredient		ATm4	AFs5	FOs5	TLt5	KMk5	KGl5	KLr5	TKi5	THg5
		PEC -Groundwater (µg/L)									
Express	Tribenuron-methyl		7,24E-03	6,39E-03	5,42E-03	4,81E-03	6,77E-03	7,35E-03	6,39E-03	6,44E-03	6,09E-03
		Risk	2	1	1	1	1	2	1	1	1
MCPA 750	MCPA		2,53E+00	2,05E+00	1,55E+00	1,13E+00	2,14E+00	2,56E+00	2,05E+00	2,07E+00	1,98E+00
		Risk	4	4	4	4	4	4	4	4	4

1 = no risk
2 = low risk
3 = moderate risk
4 = high risk

Table 12: Overall evaluation of all parameters (air, groundwater, soil and surface water) in connection with pesticide use in spring wheat production, Grue . Water table thickness = 0.3 m and water table depth: 1m.

Merchandise	Active ingredient		ATm4	AFs5	FOs5	TLt5	KMk5	KGl5	KLr5	TKi5	THg5
Express	Tribenuron-methyl		1	1	1	1	1	1	1	1	1
MCPA 750	MCPA		3	3	3	3	3	3	3	3	3

EPRIP score	EPRIP judgement	EPRIP judgement (value)
1	No	0
2-16	Negligible	1
17-81	Small	2
82-256	Present	3
257-400	Large	4
>400	Very large	5

The calibration of water table thickness resulted in a somewhat higher risk classification for MCPA and tribenuron-methyl, than compared to previous simulations (table 8). The changes were especially noticeable for MCPA, where the risk of groundwater contamination increased for all soil types. The risk of pesticide leaching in relation to tribenuron-methyl was also somewhat higher for soils grouped in hydrological class A (ATm5, KGl5) (table 9). The alteration of water table depth resulted in only small changes for the predicted environmental concentration in groundwater and changes in risk classes were only visible for the soil types FOs5 and TLt5 (table 10). Simultaneously modification of both parameters (water table depth and water table thickness), gave high risks in relation to all soil types treated with MCPA (table 11). The risk for rimsulfuron was somewhat higher for soils grouped in hydrological class A (ATm5, KGl5). The overall evaluation of EPRIP indicated a present risk for MCPA and no risk for tribenuron-methyl (table 12).

Calibrations undertaken for maximum daily rainfall did not have an effect on the simulation results (appendix 5).

4.2 EPRIP in comparison with MACRO_GV

The use of unmodified values, related to water table thickness and water table depth, resulted in great differences between output data obtained by EPRIP and MACRO_GV. In most cases, EPRIP scored much lower than MACRO_GV; this was especially noticeable for plant protection agents used in spring wheat production. However, in the case of glufosinate-ammonium, used in potato production, EPRIP scored much higher than MACRO_GV. Despite great variations in risk classifications, both models indicated a greater risk for soil types grouped in hydrological class A.

Results obtained for the calibration of EPRIP, indicated a better agreement between MACRO_GV and EPRIP. However, it is difficult to provide a clear answer in matter of agreement, since calibrations were only undertaken for four plant protection agents. More simulations should be done in order to clarify the results. Risk scores received for MCPA and metribuzin were, with few exceptions, quite similar to results obtained by MACRO_GV. In contrast, risk scores for tribenuron-methyl and rimsulfuron still differed greatly form output values gained through MACRO_GV. However, the risk was estimated as somewhat higher, for soils grouped in hydrological class A, than compared to previous simulations.

4.3 Validation – EPRIP results compared to field data

In 1996, farm wells in Grue were sampled for the first time; whereas the detection limit was 0.05 µg/L. Detected pesticides were metribuzin, metalaksyl and ETU; here values were especially high for metribuzin (8µg/L and 5µg/L) and metalaksyl (19µg/L) (Eklo et al. 2002). In the period of 1999-2000; metribuzin, bentazon, BAM, metalaksyl, MCPA, 2,4 D, propaklor and ETU were found in samples taken from farm wells in Grue. Concentrations for metribuzin varied between 0.04µg/L and 0.35µg/L; and concentrations for MCPA between 0.03µg/L and 0.05µg/L (Eklo et al. 2002) In 2007, further sampling was undertaken and concentrations of metribuzin (0.02 µg/L) and fenpropimorph (0.02µg/L and 0.05µg/L) were found (Ludvigsen et al. 2008). No pesticides were found in groundwater wells in 2008.

The risk assessment carried out with unmodified values and by means of EPRIP predicted generally lower concentrations of metribuzin and fenpropimorph than detected in the field (Eklo et al.(2002), Ludvigsen et al. (2008). However, EPRIP calculated a certain amount of risk for metribuzin applied on soils grouped in hydrological class A. Predicted values for MCPA (MCPA 750) were in good agreement with MCPA concentrations found in groundwater samples, taken from farm wells. A certain risk of pesticide leaching was indicated in relation to glufosinate-ammonium and mecoprop-p; however concentrations of these compounds were not detected in the research area.

Calibrations undertaken for the model EPRIP, resulted in higher predicted environmental concentrations in groundwater. Here, the predicted mean average concentration of metribuzin was for example 0.182µg/L, this was on the one hand much higher than concentrations found in the period of 1999- 2000, but on the other hand lower than concentrations found in 1996. EPRIP indicated high risks of pesticide leaching in matter of MCPA; this might however be an overestimation to concentrations found in the field. Generally speaking, there are great variations between the predicted concentration obtained by EPRIP and values gained through groundwater sampling out in the field. In addition, there is a lack of sufficient simulation data in respect to the calibrations undertaken for EPRIP and field data; it is therefore difficult to draw a clearly defined answer as to whether EPRIP gives valid risk estimations or not.

5. DISCUSSION

5.1 Evaluation of the risk assessment undertaken by means of the model EPRIP

Risk evaluations, undertaken with unmodified data, predicted that there was no or low risk in relation to groundwater contamination by pesticides in potato and spring wheat production, in the area Grue. Further, it was indicated that soils grouped in hydrological class A had a greater leaching potential than other soils. This can be explained by the fact that soils grouped in hydrological class A are well drained and low in organic matter content; increasing the vulnerability of pesticide leaching to groundwater. There were three active ingredients that scored somewhat higher than the other compounds, examined in this study; those compounds were: glufosinate-ammonium, mecoprop-p and MCPA. It did not surprise that the risk for MCPA and mecoprop-p was estimated to be somewhat higher, since those compounds already indicated a high leaching potential in MACRO_GV, and MCPA in addition was found in drinking water wells in Grue. In contrast, the risk score for glufosinate-ammonium was highly questionable. On the one side, it is true that glufosinate-ammonium has a water solubility that might indicate a greater leaching potential, but on the other side this compound is also rapidly biodegraded, which in turn reduces the risk for pesticide leaching to groundwater. A study undertaken by Almvik et al. (2008a) demonstrated that the risk of pesticide leaching in matter of glufosinate-ammonium was classified as low. Results obtained by MACRO_GV indicated the same. In addition, it was found that the bounding to soil particles, such as clay, might play an important part in the retention, of the compound in, the soil. A comparison of chemical properties registered in the EPRIP database and the Footprint database (last accessed 03.05.2010) revealed that EPRIP used a much lower KOC value (EPRIP utilizes a KOC value of 16 l kg^{-1}, whereas the registered value in the Footprint database is 755 l kg^{-1}) in the simulation process, than recorded in the footprint database. This might also be a reason as to why glufosinate-ammonium scored as high as it did. Pesticides with high KOC values are expected to be less vulnerable to leaching than pesticides with low KOC value.

The use of calibrated data resulted in risk classifications that indicated higher risk for groundwater contamination by pesticides, than compared to previous simulations. It was clearly indicated that water table thickness had a great impact on the predicted environmental concentration in groundwater, and hence also on risk classification. This can be explained by the approach EPRIP uses for the estimation of the PEC in groundwater. In order to estimate the PEC, the model takes into account the application dose of the active ingredient, the fraction that is intercepted by the soil and lost by drift, the soil porosity and the water table thickness (Balderacchi et al. 2007). EPRIP considers the dilution of the pesticide in groundwater, meaning: the lower the water table thickness, the higher the predicted environmental concentration in the groundwater. This was especially noticeable for the compounds metribuzin and MCPA, which scored much higher during the application of calibrated values, than with the use of unmodified values. In contrast, changes for tribenuron-methyl and rimsulfuron were less noticeable, which could be connected with the fact that both of these compounds are applied at low concentrations to agricultural fields. On the one side, low dose pesticides are rapidly degraded in the soil, but on the other side they often have high KOC values, indicating a moderate-high risk for leaching to groundwater. A soil column study undertaken by Almvik et al. (2008b) found that low dose pesticides might constitute a potential hazard for groundwater contamination. Here, tribenuron-methyl, amidosulfuron, iodosulfuron-methyl and metsulfuron-methyl were tested and concentrations, of those compounds, were found in leached water from the soil columns. One has to keep in mind, that leaching studies undertaken in the laboratory cannot be directly conveyed to situations in the field; however simulations results obtained with MACRO_GV also indicated a moderate or high risk associated with the use of low dose pesticides. Further, tribenuron methyl has been found, several times, in water samples in Sweden (Almvik et al. 2008b). This might signify that EPRIP underestimates the risk for low dose pesticides used in agriculture. However, a study undertaken by Kjær et al. (2007) found no evidence of sulfonylurea (low dose herbicides) leaching to groundwater in relation to application on agricultural fields in Denmark. In addition, no concentrations were detected in water samples taken from Grue either. It is therefore difficult to draw a clear answer as to whether the estimation by EPRIP is a reliable one.

<u>Evaluation of the final EPRIP score for all compartments</u>

The final EPRIP, score for all parameters (soil, air, groundwater, and surface water), gave an estimation of no risk for almost all pesticides used in potato and spring wheat production, in Grue. The only exception was esfenvalerate, which scored somewhat higher. Here, risk points were especially high for the compartment air, followed by the compartment surface water. Esfenvalerate is known to be toxic to aquatic organisms, thus the greater risk for surface water was not unexpected. However, the high score for air is questionable; since esfenvalerate is almost non-toxic via inhalation (Cornell University 1994).This can be explained by the lack of data in relation to LC_{50} by inhalation for rats (This value is not registered in the EPRIP database). The final EPRIP score for esfenvalerate is therefore not representative and should not be attended to. Scores obtained, for calibrated data, resulted in a greater variation in risk classification for pesticides, used in Grue.

5.2 A comparison of the risk models EPRIP and MACRO_GV

Differences between EPRIP and MACRO_GV can be explained by the different approaches the models are using in order to calculate the predicted environmental concentration in groundwater. EPRIP considers the water table thickness and the dilution of the pesticide within the groundwater, whereas MACRO_GV calculates the concentration for a depth of 1 meter and under consideration of the annual recharge (figure 8). Therefore, calibrations (in matter of water table depth and water table thickness) have been undertaken in order to create a better foundation for the comparison of the

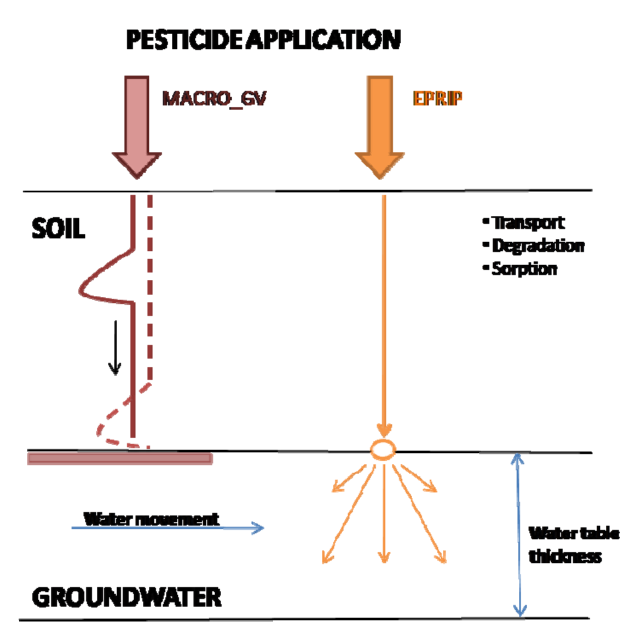


Figure 8: Difference between MACRO_GV and EPRIP, regarding approaches used for the determination of the predicted environmental concentration in groundwater

two models. Simulation results obtained, after the calibration of EPRIP, demonstrate a far better agreement between MACRO_GV and EPRIP, than simulations undertaken without modified values. Over half of the simulation accomplished for MCPA and metribuzin scored in the same risk class as MACRO_GV. However, the agreement of results obtained for low dose pesticides was not as good. Here, both models indicated a higher risk for soils grouped in hydrological class A; apart from that EPRIP scored much lower than MACRO_G.

This might be explained by the different approaches, used by the two models, to handle sorption. EPRIP does, for instance, not consider the Freundlich equation, whereas MACRO_GV does; this could be the reason for the higher risk classification of low dose pesticides in MACRO_GV. Only few simulations have been carried out for the calibration of EPRIP and it is therefore difficult to draw a clear conclusion as to whether these two models are in good agreement with each other or not. In order to give a better evaluation of the consistency between MACRO_GV and EPRIP, more simulations should be carried out.

5.3 Validation of simulation results obtained by EPRIP

In three of four pesticide monitoring studies, metribuzin concentrations have been found in water samples taken from farm wells in Grue. Detected concentrations varied between 0.02µg/L and 8µg/L, indicating that there is a present risk for groundwater contamination by metribuzin. This has also been shown in risk classifications obtained by MACRO_GV and EPRIP (calibrated). Environmental concentrations predicted by EPRIP (calibrated) were allocated within the detected range of metribuzin achieved in field studies. However, the use of unmodified data resulted in predicted concentration much lower than detected values in the field. Studies undertaken by Benoit et al. (2007) and Stenrød et al. (2008) indicate that the risk of leaching, in matter of metribuzin, actually is higher in areas with cold climate compared to warm areas. This might indicate that the calibration of EPRIP is necessary in order to obtain reliable information in relation to risk classification.

In the period 1999-2000, MCPA has been found in groundwater wells in Grue. Detected values varied between 0.04µg/L and 0.35µg/L, which were in good agreement with predicted values by EPRIP. Calibrations undertaken for EPRIP resulted in an estimation of much higher values than predicted in the field. In general, predicted environmental concentrations for metribuzin and MCPA were in much better agreement with field data, when only one parameter (water table thickness) was adjusted. The modification of both parameters was often followed by the overestimation of the predicted environmental concentration.

There was no agreement between detected concentrations of fenpropimorph in the field and predicted environmental concentration by EPRIP; then again, no risk was estimated by MACRO_GV either. Fenpropimorph has only been detected once, so this case might be related to point source pollution.

Generally speaking, it seems that there is a certain degree of agreement between predicted environmental concentration and detected concentration in the field. However, only few simulations have been undertaken for calibrated data and the amount of simulations is therefore not sufficient to draw a clear conclusion. More simulations should be conducted in order to clarify the degree of consistency between field data and risk assessment model. The same accounts for sampled data in the field; only few data is available, which makes it difficult to validate the model

5.4 A world without pesticides?

Pesticide risk models have been developed in order to monitor the risk associated with agrochemicals, to help farmers to choose the most environmental friendly plant protection strategy, to increase scientific knowledge and to support political decision making processes. However, the question arises as to whether it is really necessary to use pesticides within agricultural production in the first place. As mentioned earlier, pesticides have several negative side-effects on the environment and human health. Farmers are especially exposed to health risks caused by pesticides. The world health organization (WHO) has estimated that about 3 million people are poisoned by pesticides every year and that approximately 200 000 of them die by the consequences of poisoning (Eikum s.a.).The advancement of science has undeniably provided us with new knowledge, tools and possibilities to reduce those impacts, but the past has shown several times that the scientific knowledge we have today might be outmoded in a couple of years. The pesticide DDT, for instance, was used in a long period before it was banished from agricultural production, due to its toxicity, in many countries. The environmental risk for this compound had been totally underestimated, resulting in negative consequences for wildlife, especially birds. This case illustrates that our knowledge is still imperfect and that this uncertainty should inure to the benefit of nature. People tend to forget that we only have one planet. Further, it is questionable whether scientific results are trustworthy and if; will they have an impact on decision making processes? Firstly scientific work is often sponsored by private sectors; raising the question of credibility. Who possible would bite the hand that feeds you? Secondly, big companies tend to have a tremendous amount of influence on political decisions. Politicians are in many cases also executive committee members in influential corporations, which could (1) cause a conflict of interests and (2) might actually influence the decision making process. Either way, the use of agrochemical use is only a short term solution and should be reconsidered in favor for more sustainable ones.

The application of pesticides is often justified with the argument that we need to grow more food, because of an increasing world population. However, world hunger is not only a question of production but also of distribution, politics, economics, poverty etc. In fact, it is claimed that the world produces enough food to feed the whole world population (Greenpeace s.a.). Nevertheless, there still are many parts of the world where people suffer from malnutrition. Globalization and free trade has encouraged producers from developing countries to explore new and more profitable market opportunities abroad. This has on the one hand resulted in large quantities of exported food and on the other hand lead to scarceness of available food for the own population (Knight 1998). This fact can be clearly demonstrated by the example of India. The country early adopted new technologies and production methods. In the 1990s India became self-sufficient in food (Halberg et al. 2009). However, agricultural production is mainly aimed towards export and approximately 231 million people in India still suffer from the lack of food (Peramaiyan et al. 2009). In some countries is the economic situation so bad that people are too poor to purchase food grown on their own countries soil. Big companies/ producers will hence orientate towards more lucrative alternatives, a vicious circle.

Another big issue is the mentality of industrialized countries. In a world of plenty people tend to waste large amounts of resources. We are throwaway society. In Great Britain, people throw away 30-40 % of all produced and imported food (Eikum s.a.). Forty percent of all agricultural products produced in the US are never consumed (Food production daily 2004). In 2004, Norwegian households produced 440 000 tons of food waste; this was an increase of 25 % from 1999. In 2006, the total amount of food waste, considering all sectors, was estimated to 1 200 000 ton (Eikum s.a.). In several countries dumpster diving has become a favorite “sport”; preferred spot: the supermarket. Grocery chuck large amount of food every day, often due to the dare of expiry. For many people this is the only way to obtain something to eat. Some supermarkets have arrangements with social services that hand it out to poor people. For other people dumpster diving is a political statement that aims to highlight the drawbacks of our society The production of food waste goes hand in hand with the depletion of our nature.

Low food prices seem to encourage carelessness among end-consumers. Never has a consumer used so little of his income on food as today. And still they are complaining. Food has lost its value and hence the constraint to waste it is low. This applies at least for industrialized countries. The implication of this phenomena is that farmers struggle to maintain a suffice income to continue their production. Many farmers have been forced to quit or to increase their farmland. During the last couple of years industrial farming has become more and more common.

Another argument that has been constantly used in favor for the use of pesticides is that organic farming does not obtain the same yields as conventional agriculture. It has been argued that organic farming systems would take more space and hence were not suitable to feed the world population without clearing more area for agricultural production. Further it has been stated that there isn`t enough organic manure available in order to compensate for the lack of fertilizers. However, recent studies (Badgley et al. 2007; Halberg et al. 2009) have shown that these arguments are not solid and that organic farming should be reconsidered as a alternative to pesticides. It has been revealed that the benefits of organic farming systems are highest for developing countries. In Brazil, maize and wheat yields increased nearly by 50 % after the adaption of green manure and nitrogen fixing legumes. Coffee growers in Mexico reported an increase in the weight of coffee beans after the converting to organic agriculture (Hamer & Anslow 2008). A study undertaken by (Halberg et al. 2009) demonstrated that two of three research areas in India increased or stabilized their yield after adapting to organic farming methods. An analysis of more than 286 organic conversions from 57 countries concealed that the average yield increased by 64 % (Hamer & Anslow 2008). However, industrialized countries seem not to have the same positive trend. Badgley et al. (2007) found that yield either decreased or stayed the same after the conversion to organic agriculture in industrialized countries. On the other hand it has been shown that yields are expected to increase again after a couple of years (Hamer & Anslow 2008).

Based upon the assumptions above it seems absolutely possible to feed the world with organic agriculture. This might also be the most desirable solution. The Austrian farmer Sepp Holzer puts it this way: “Nature is always right, the human race fools itself when violating the principles of nature” (“Die Natur hat immer Recht, ist immer richtig, der Mensch betrügt sich selbst wenn er die Gesetze der Natur missachtet”). Nature is a system in balance, we as humans disturb this balance by adding chemical fertilizers, pesticides and genetically modified organisms. In the end we will pay the price for it; we are already digging our own grave.

Organic farming would not only reduce the use of pesticides, it would also result in several other benefits. For instance, it is likely to expect that organic agriculture increases food security in developing countries and hence reduces malnutrition and hunger. The labor intensity of organic farms could contribute to the creation of new job possibilities and hence to the reduction of poverty and the dependence on industrialized countries. Further, it has been shown that organic agriculture is less energy and water consuming than their conventional counterpart. Biodiversity is increased and it has been concealed that organic products contain lower levels of nitrate, pesticides and veterinary drug residues. Some studies have also indicated that the level of essential nutrients and antioxidants is higher in organic than in conventional. However, this topic is still highly discussed between scientists.

So, the question is: what should we do? Should we just start a large scale conversion to organic farming? Well, the answer is: no! In order to create a farming system that is sustainable and benefits all parts of the system, many factors have to be considered. For instance, what is the use of organic agriculture, when the farmer has to quit farming due to economical issues? Nobody would benefit of such a situation; that is why the consideration of the social, economical, agronomical and environmental dimension is so important. Integrated pest management (IPM) is a suitable alternative to organic farming. It applies all management options in order to suppress pests beneath an economical threshold without causing damage for the environment and human health.

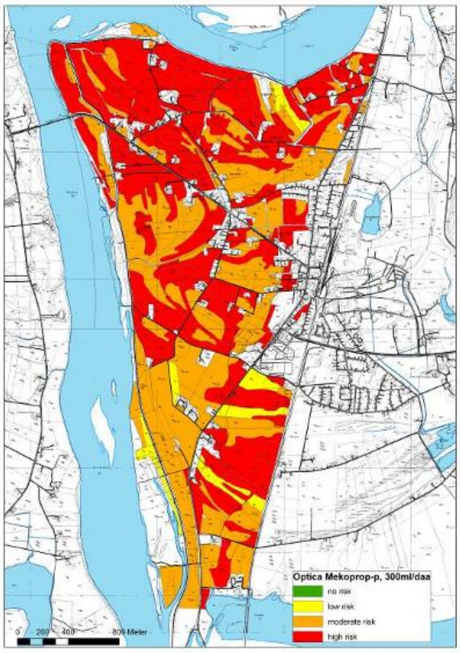


Figure 9: Risk map developed in relation to mecoprop-p used on soils in Grue (Eklo et al. 2009)

Preventive measurements, such as crop rotation, the use of pest resistant plants and the planting of pest free crops; are very important in relation to IPM. When preventive actions are not sufficient anymore, measurement such as mechanistic control and agrochemical use can be considered. Here, pesticide risk models could be used in order to identify the most suitable and environmental friendly pesticides. The models can also be used for the creation of risk maps that can help farmers, more easily, to identify the potential risk of pesticide leaching on their land (figure 9). Especially helpful might be risk models that are providing risk estimates for more than one environmental compartment (for example EPRIP), because they give a better evaluation of the overall risk associated with a pesticide. When threats are identified, more advanced models could be used to calculate the actual predicted environmental concentrations and to study the environmental behavior of pesticides. However, this might be more appropriate for scientific purposes.

6. CONCLUSION

Risk evaluations undertaken for potato and spring wheat production, by means of the risk indicator model EPRIP, indicated that the agreement, with MACRO_VG and field data, was best when simulations were accomplished with calibrated values, in relation to water table depth and water table thickness. Here, the modification of both parameters simultaneously gave a good consistency between EPRIP and MACRO_GV, in respect to metribuzin and MCPA. In contrast, the agreement for low dose pesticides was not as good. In a field study, concentrations of metribuzin and MCPA were detected in groundwater samples in Grue; risk classification for MCPA and metribuzin reflected those findings. However, due to limited time, there only have been undertaken 4 simulations, in matter of calibrated data. More simulations have to be undertaken in order to support the results of this study and to be able to draw a clear conclusion.

Handled in the right way, risk indicator models can be a good advisory tool for farmers. EPRIP, for instance, is easy to handle, does not require large amounts of data and gives a risk evaluation for more than one environmental compartment. However, it might be difficult for farmers to obtain necessary input data; because some of the areas in Norway are not mapped yet and little data is available in respect to soil properties and other input data. In additions, a regular update of the pesticide database should be undertaken in order to provide reliable results. It would be most suitable if one could obtain automatically updates, where farmers don’t have to change values manually. Risk evaluations with a risk indicator model, should also be followed up by field studies in order to ensure the prober adjustment of the model. In general, one should aim for the further reduction of pesticide use in agricultural practice. These changes will not occur overnight, but will probably take long time. Here pesticide risk models can be a good supporting tool within integrated pest management, choosing the most suitable and environmentally friendly pesticide for active pest control.

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APPENDICES

Appendix 1: Development of pesticide sales in the period of 1980 – 2009 (Mattilsynet 2010)

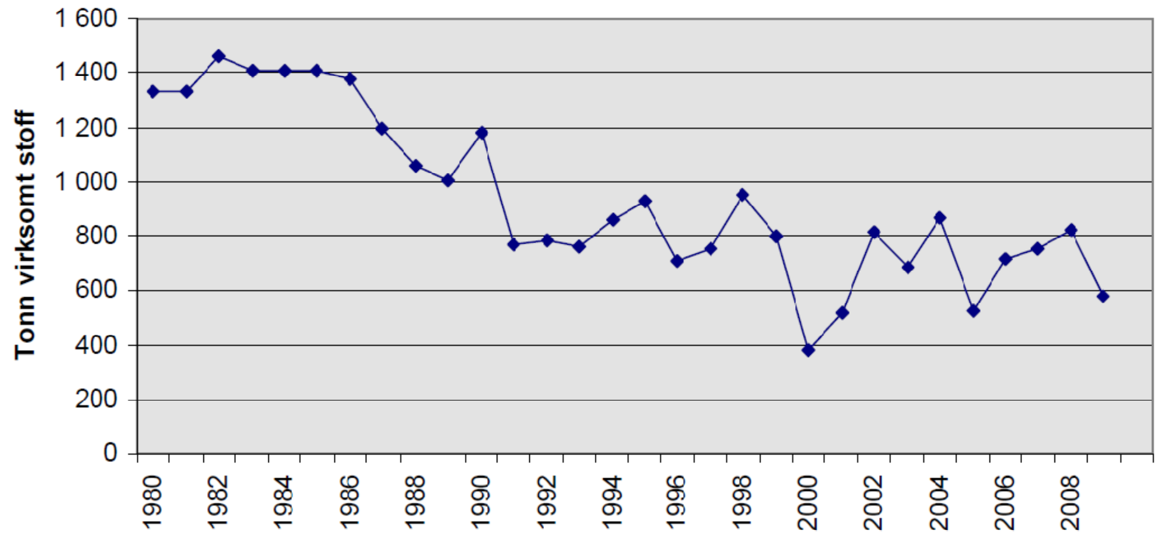

Figure I: Development of sales in the period of 1980 – 2009 (Mattilsynet 2010)

Appendix 2: Description of soil types

All soils are developed in alluvial sediments. The classification is according to World Reference Base for Soil Resources, 2006 (WRB).

Arenosols:

WRB-unit: **Haplic Arenosol**
Description: Well drained soil with sand or loamy sand texture from 20 to 100 cm depth.
Series: **ATm**

Typical profile:
Ap (20-30 cm thick): 1 - 2 % organic C, fine sandy loam or loamy fine sand.
Bw and C (to 1 m depth): fine sand or loamy fine sand.

WRB-unit: **Endogleyic Arenosol**

Description: Moderately well drained soil with sand or loamy sand texture from 20 to 100 cm depth. Gleyic pattern within 50 to 100 cm depth indicates periods of high ground water level.

Series: **AFs**

Typical profile:

Ap (20-30 cm thick): 2 - 3 % organic C, fine sandy loam or loamy fine sand.
Bw and C (to 50 - 70 cm depth): fine sand or loamy fine sand.
Cg (to 1 m depth): texture as above, gleyic colour pattern.

Cambisols:

WRB-unit: **Fluvic Cambisol**
Description: Well drained soil with soil structure in the B-horizon and a stratified C-horizon.
Series: **KGl**

Typical profile:

Ap (20-30 cm thick): 1 - 2 % organic C, fine sandy loam or silt loam
Bw (to 40 - 60 cm depth): fine sandy loam or silt loam
C (to 1 m depth): stratified fine sandy loam/fine sand/silt loam

WRB-unit: **Endostagnic Fluvic Cambisol**

Description: Moderately well drained soil with soil structure in the B-horizon and a stratified C-horizon. Horizons between 50 and 100 cm depth are periodically saturated with stagnated surface water.

Series: **KLr**

Typical profile:

Ap (20-30 cm thick): 2 - 3 % organic C, fine sandy loam or silt loam
Bw (to 50 - 60 cm depth): fine sandy loam or silt loam
Cg (to 1 m depth): stratified fine sandy loam/fine sand/silt loam, stagnic colour pattern.

WRB-unit: **Endostagnic Fluvic Cambisol**

Description: Moderately well drained soil with soil structure in the B-horizon and a stratified C-horizon. Horizons between 50 and 100 cm depth are periodically saturated with stagnated surface water.
Series: **KMk**

Typical profile:

Ap (20-30 cm thick): 2 - 3 % organic C, fine sandy loam or silt loam
Bw and Cg (to 60 - 80 cm depth): fine sandy loam or silt loam, stagnic colour pattern below 50 cm depth.
C (to 1 m depth): stratified medium/coarse sand or loamy sand.

Stagnosols:

WRB-unit: **Fluvic Stagnosol**

Description: Poorly drained soils that are periodically saturated with stagnated surface water within 50 cm depth, and with a stratified C-horizon within 1 m depth.
Series: **TKi**

Typical profile:

Ap (20-30 cm thick): 2 - 3 % organic C, fine sandy loam or silt loam.

Bg and Cg (to 1 m depth): fine sandy loam or silt loam with stagnic colour pattern, stratified below 50 cm depth.

WRB-unit: **Fluvic Stagnosol**
Description: Poorly drained soils that are periodically saturated with stagnated surface water within 50 cm depth, and with a stratified C-horizon within 1 m depth.
Series: **THg**

Typisk profil:

Ap (20-30 cm thick): 2 - 3 % organic C, fine sandy loam or silt loam

Bg and Cg (to 50 - 70 cm depth): fine sandy loam or silt loam with stagnic colour pattern.

Cg/C (to 1 m depth): stratified medium/coarse sand or loamy sand.

WRB-unit: **Umbric Fluvic Stagnosol**
Description: Poorly drained soil that are periodically saturated with stagnated surface water within 50 cm depth and with a > 20 cm thick, dark coloured surface horizon which normally has low base saturation (< 50 %), stratified C-horizon within 1 m depth.
Series: **TLt**

Typical profile:

Ap (20-30 cm thick): > 5 % organic C, silt loam or fine sandy loam.

Bg and Cg (to 1 m depth): silt loam or fine sandy loam with stagnic colour pattern, stratified below 50 cm depth.

Appendix 3: Results obtained by MACRO_GV

Table I: Risk classification of pesticides, used in potato production, according to predicted environmental concentration in groundwater and hydrological class. Grue. Obtained by MACRO_GV

Handelspreparat	Aktivt stoff	ATm4	AFs5	FOs5	TLt5	KMk5	KGI5	KLr5	TKi5	THg5	Dose (NAD)
Rizolex 50 FW	Tolklofosmetyl	1	1	1	1	1	1	1	1	1	75 ml/daa
Fenix	Aklonifen	1	1	1	1	1	1	1	1	1	175 ml/daa
Finale	Glufosinat	1	1	1	2	1	1	1	1	1	500 ml/daa
Focus Ultra	Sykloksydim	2	1	2	2	2	2	1	1	2	600 ml/daa
Select	Kletodim	1	1	1	1	1	1	1	1	1	50 ml/daa
Sencor	Metribuzin	4	2	2	3	3	4	2	3	2	30 g/daa
Titus	Rimsulfuron	4	3	3	3	3	4	3	3	3	5 g/daa
Acrobat WG	Dimetomorf	1	1	1	3	2	1	1	1	1	200 g/daa
	Mankozeb	1	1	1	1	1	1	1	1	1	
Dithane NewTec	Mankozeb	1	1	1	1	1	1	1	1	1	200 g/daa
Electis	Zoksamid	2	1	1	3	2	2	1	1	1	180 g/daa
	Mankozeb	1	1	1	1	1	1	1	1	1	
Sereno WG	Fenamidon										125 g/daa
	Mankozeb	1	1	1	1	1	1	1	1	1	
Shirlan	Fluazinam	2	1	1	2	2	2	1	1	1	40 ml/daa
Tattoo	Propamokarb	1	1	1	2	1	1	1	1	1	400 ml/daa
	Mankozeb	1	1	1	1	1	1	1	1	1	
Fastac 50	Alfacypermetrin	1	1	1	1	1	1	1	1	1	40 ml/daa
Karate 2.5 WG	Lambda-cyhalotrin	1	1	1	1	1	1	1	1	1	80 g/daa
Sumi-Alpha	Esfenvalerat	1	1	1	1	1	1	1	1	1	30 ml/daa
Reglone	Dikvat dibromid	1	1	1	1	1	1	1	1	1	300 ml/daa

1 = ingen risiko
2 = lav risiko
3 = moderat risiko
4 = høy risiko

Table II: Risk classification of pesticides, used in spring wheat production, according to predicted environmental concentration in groundwater and hydrological class. Grue. Obtained by MACRO_GV

Handelspreparat	Aktivt stoff	ATm4	AFs5	FOs5	TLt5	KMk5	KGl5	KLr5	TKi5	THg5	Dose (NAD)
Actril 3-D	Ioksynil	1	1	1	1	1	1	1	1	1	300 ml/daa
	Diklorprop - p	4	4	4	4	4	4	4	4	4	
	MCPA	1	1	1	3	2	1	1	1	1	
Ally 50 ST	Metsulfuron - metyl	4	3	3	3	3	4	3	3	3	1.2 g/daa
Ally Class 50 WG	Metsulfuron - metyl	4	3	3	3	3	4	3	3	3	5 g/daa
	Karfentrazon - etyl	4	3	3	3	3	4	3	4	3	
Ariane S	Fluroksypyr 1-metylheptylester	4	3	3	3	3	4	3	4	3	250 ml/daa
	Klopyralid	4	4	4	4	4	4	4	4	4	
	MCPA	1	1	2	3	3	1	1	1	1	
Roundup ECO	Glyfosat	1	1	1	1	1	1	1	1	1	400 ml/daa
Express	Tribenuron - metyl	4	3	3	3	3	4	3	3	3	1 tabl./5 daa
Harmony Plus 50 T	Tifensulfuron - metyl	1	1	1	1	1	1	1	1	1	1.5 g/daa
	Tribenuron - metyl	4	3	2	2	3	4	3	3	2	
Hussar	Mefenpyr - dietyl										20 g/daa
	Jodsulfuron	3	2	2	2	2	3	2	2	1	
MCPA 750	MCPA	4	1	3	4	4	4	1	4	3	400 ml/daa
Optica Mekoprop - P	Mekoprop - p	4	2	3	3	3	4	3	3	2	300 ml/daa
Primus	Florsulam	1	1	1	1	1	1	1	1	1	10 ml/daa
Puma Extra	Fenoksaprop - p - etyl	1	1	1	1	1	1	1	1	1	120 ml/daa
	Mefenpyr - dietyl										
Starane	Fluroksypyr 1-metylheptylester	4	4	4	4	4	4	4	4	4	200 ml/daa
Acanto Prima	Cyprodinil	1	1	1	1	1	1	1	1	1	150 g/daa
	Pikoksystrobin										
Amistar	Azoksystrobin	1	1	1	3	2	1	1	1	1	100 ml/daa
Amistar Duo	Azoksystrobin	3	1	2	3	3	3	1	1	1	100 ml/daa
	Propikonazol	2	1	2	3	3	2	1	1	1	
Handelspreparat	**Aktivt stoff**	**ATm4**	**AFs5**	**FOs5**	**TLt5**	**KMk5**	**KGl5**	**KLr5**	**TKi5**	**THg5**	**Dose (NAD)**
Amistar Pro	Azoksystrobin	3	1	2	3	3	3	1	2	1	200 ml/daa
	Fenpropimorf	1	1	1	1	1	1	1	1	1	
Comet	Pyraklostrobin	1	1	1	1	1	1	1	1	1	100 ml/daa
Comet Plus	Fenpropimorf	1	1	1	1	1	1	1	1	1	200 ml/daa
	Pyraklostrobin	1	1	1	1	1	1	1	1	1	
Forbel	Fenpropimorf	1	1	1	1	1	1	1	1	1	100 ml/daa
Mentor	Fenpropimorf	1	1	1	1	1	1	1	1	1	50 ml/daa
	Kresoksimmetyl	1	1	1	1	1	1	1	1	1	
Stereo 312.5 EC	Propikonazol	2	1	1	3	2	2	1	1	1	150 ml/daa
	Cyprodinil	1	1	1	1	1	1	1	1	1	
Stratego 250 EC	Propikonazol	2	1	2	3	3	2	1	1	1	100 ml/daa
	Trifloksystrobin										
Stratego 312.5 EC	Propikonazol	2	1	2	3	3	2	1	1	1	100 ml/daa
	Trifloksystrobin										
Zenit 575 EC	Fenpropidin										100 ml/daa
	Propikonazol	2	1	2	3	3	2	1	1	1	
Fastac 50	Alfacypermetrin	1	1	1	1	1	1	1	1	1	40 ml/daa
Karate 2.5 WG	Lambda - cyhalotrin	1	1	1	1	1	1	1	1	1	80 g/daa
Perfekthion 500 S	Dimetoat	2	1	1	2	1	2	1	1	1	80 ml/daa
Pirimor	Pirimikarb	1	1	1	1	1	1	1	1	1	50 g/daa
Sumi Alpha	Esfenvalerat	1	1	1	1	1	1	1	1	1	30 ml/daa

1 = ingen risiko
2 = lav risiko
3 = moderat risiko
4 = høy risiko

Appendix 4: Input parameters (EPRIP)

Table III: Soil parameters

	ATm4	AFs5	FOs5	TLt5	KMk5	KGl5	KLr5	TKi5	THg5
Sand (%)	79,4	39	28	4	1	31	35	38	35
Silt (%)	17,1	54	62	86	96	63	60	57	58
Clay (%)	3,5	7	10	10	3	6	5	5	7
Slope (%)	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2
Bulk density (kg m-3)	1460	1420	1350	1430	1510	1500	1420	1430	1350
Water table thickness (m)	10	10	10	10	10	10	10	10	10
Groundwater recharge (m y-1)	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3
Water table depth (m)	3,75	3,75	3,75	3,75	3,75	3,75	3,75	3,75	3,75

Table IV: Applied values for the treatment section, for potato production

Merchandise	Active ingredient	Phenological state	Incorporation depth (cm)	Application rate (g ha-1)	Number of applications	Interval (d)
Fenix	*Aclonifen*	Bare soil	4	1050	1	0
Finale	*Glufosinate-ammonium*	Bare soil	4	915	1	0
Focus Ultra	*Cycloxydim*	Development of vegetativ plant parts	4	600	1	0
Select	*Clethodim*	Development of vegetativ plant parts	4	120	1	0
Sencor	*Metribuzin*	Emergence	4	211,5	1	0
Titus	*Rimsulfuron*	Development of vegetativ plant parts	4	12,5	2	14
Acrobat WG	*Dimetomorph*	Development of vegetativ plant parts	4	180	2	14
	Mancozeb	Development of vegetativ plant parts	4	1200	2	14
Dithane NewTec	*Mancozeb*	Development of vegetativ plant parts	4	1540	4	14
Electis	*Zoxamide*	Development of vegetativ plant parts	4	149,4	4	10
	Mancozeb	Development of vegetativ plant parts	4	1200,6	4	10
Sereno WG	*Fenamidone*	Development of vegetativ plant parts	4	125	3	10
Shirlan	*Mancozeb*	Development of vegetativ plant parts	4	625	3	10
	Fluazinam	Development of vegetativ plant parts	4	200	4	12
Tattoo	*Propamocarb*	Development of vegetativ plant parts	4	992	4	12
	Mancozeb	Development of vegetativ plant parts	4	1208	4	12
Fastac 50	*Alpha-cypermethrin*	Development of vegetativ plant parts	4	20	1	0
Karate 2.5WG	*Lambda-cyhalothrin*	Development of vegetativ plant parts	4	20	1	0
Sumi-Alpha	*Esfenvalerate*	Development of vegetativ plant parts	4	15	1	0
Reglone	*Diquat dibromide*	Tuber formation	4	1122	1	0
Rizolex 50 FW	*Tolclofos methyl*	Bare soil	4	375	1	0

Table V: Applied values for the treatment section, for spring wheat production

Merchandise	Active ingredient	Phenological state	Incorporation depth (cm)	Application rate (g ha-1)	Number of applications	Interval (d)
Actril 3-D	Ioxynil	3 leaves unfolded	4	198	1	0
	Dichlorprop-p	3 leaves unfolded	4	498	1	0
	MCPA	3 leaves unfolded	4	282	1	0
Ally 50 ST	Metsulfuron-methyl	3 leaves unfolded	4	6	1	0
Ally Class 50 WG	Metsulfuron-methyl	3 leaves unfolded	4	5	1	0
	Carfentrazone -ethyl	3 leaves unfolded	4	20	1	0
Ariane S	Fluroxypyr meptyl	3 leaves unfolded	4	100	1	0
	Clopyralid	3 leaves unfolded	4	50	1	0
	MCPA	3 leaves unfolded	4	500	1	0
Roundup ECO	Glyphosate	3 leaves unfolded	4	1440	1	0
Express	Tribenuron-methyl	3 leaves unfolded	4	7,5	1	0
Harmony Plus 50 T	Thifensulfuron - methyl	3 leaves unfolded	4	5,0	1	0
	Tribenuron-methyl	3 leaves unfolded	4	2,5	1	0
Hussar	Mefenpyr - diethyl	3 leaves unfolded	4	30	1	0
	Iodosulfuron	3 leaves unfolded	4	10	1	0
MCPA 750	MCPA	3 leaves unfolded	4	3000	1	0
Optica Mecoprop-P	Mecoprop-p	3 leaves unfolded	4	1800	1	0
Primus	Florasulam	3 leaves unfolded	4	5	1	0
Puma Extra	Fenoxaprop-p-ethyl	2 true leaves	4	82,8	1	0
	Mefenpyr - diethyl	2 true leaves	4	91,2	1	0
Starane	Fluroxypyr meptyl	3 leaves unfolded	4	360	1	0
Acanto Prima	Cyprodinil	Beginning of stem elongation	4	450	1	0
	Picoxystrobin	Beginning of stem elongation	4	120	1	0
Amistar	Azoxystrobin	leaf development	4	250	1	0
Amistar Duo	Azoxystrobin	leaf development	4	200	2	35
	Propiconazole	leaf development	4	125	2	35
Amistar Pro	Azoxystrobin	leaf development	4	200	2	35
	Fenpropimorph	leaf development	4	560	2	35
Comet	Pyraclostrobin	Beginning of stem elongation	4	250	1	0
Comet Plus	Fenpropimorph	Beginning of stem elongation	4	750	1	0
	Pyraclostrobin	Beginning of stem elongation	4	200	1	0
Forbel	Fenpropimorph	leaf development	4	750	1	0
Mentor	Fenpropimorph	Beginning of stem elongation	4	150	1	0
	Kresoxim-methyl	Beginning of stem elongation	4	75	1	0
Stereo 312.5 EC	Propiconazole	Beginning of stem elongation	4	93,8	2	28
	Cyprodinil	Beginning of stem elongation	4	375	2	28
Stratego 250 EC	Propiconazole	Beginning of stem elongation	4	125	1	0
	Trifloxystrobin	Beginning of stem elongation	4	125	1	0
Stratego 312.5 EC	Propiconazole	leaf development	4	125	2	21
	Trifloxystrobin	leaf development	4	187,5	2	21
Zenit	Fenpropidin	leaf development	4	450	2	21
	Propiconazole	leaf development	4	125	2	21
Fastac 50	Alpha cypermethrin	3 leaves unfolded	4	20	1	0
Karate 2.5 WG	Lambda-cyhalothrin	2 true leaves	4	20	1	0
Perfekthion 500 S	Dimethoate	3 leaves unfolded	4	400	1	0
Pirimor	Primicarb	leaf development	4	250	1	0
Sumi-Alpha	Esfenvalerate	leaf development	4	15	2	14

Table VI: Climatic parameters

Maximum daily rainfall (mm)	36,1
Annual mean rainfall (mm)	635
Annual mean temperature (˚C)	3,3

Water body (Gruetjern)

Width = 25 meter   Depth = 2 meter

Scenario

Water body distance (m) = 10

Perimeter (m) = 400

Area (m^2) = 10 000

Organic carbon content (%)	ATm5 = 1.5	TLt5 = 6	KLr5 = 2.5
	AFs5 = 2.5	KMk5 = 2.5	TKi5 = 2.5
	FOs5 = 4	KGl5 = 1.5	THg5 = 2.5

Appendix 5: Results obtained by EPRIP

Table VII: Overall evaluation of all parameters (air, groundwater, soil and surface water) in connection with pesticide use in potato production, Grue.

Merchandise	Active ingredient	ATm4	AFs5	FOs5	TLt5	KMk5	KGl5	KLr5	TKi5	THg5	Dose (NAD)
Rizolex 50 FW	Tolclofos methyl	1	1	1	1	1	1	1	1	1	75 ml/daa
Fenix	Aclonifen	1	1	1	1	1	1	1	1	1	175 ml/daa
Finale	Glufosinate-ammonium	1	1	1	1	1	1	1	1	1	500 ml/daa
Focus Ultra	Cycloxydim	1	1	1	1	1	1	1	1	1	600 ml/daa
Select	Clethodim	1	1	1	1	1	1	1	1	1	50 ml/daa
Sencor	Metribuzin	1	1	1	1	1	1	1	1	1	30 g/daa
Titus	Rimsulfuron	1	1	1	1	1	1	1	1	1	5 g/daa
Acrobat WG	Dimetomorph	1	1	1	1	1	1	1	1	1	200 g/daa
	Mancozeb	1	1	1	1	1	1	1	1	1	
Dithane NewTec	Mancozeb	1	1	1	1	1	1	1	1	1	200 g/daa
Electis	Zoxamide	1	1	1	1	1	1	1	1	1	180 g/daa
	Mancozeb	1	1	1	1	1	1	1	1	1	
Sereno WG	Fenamidone	1	1	1	1	1	1	1	1	1	125 g/daa
	Mancozeb	1	1	1	1	1	1	1	1	1	
Shirlan	Fluazinam	1	1	1	1	1	1	1	1	1	40 ml/daa
Tattoo	Propamocarb	1	1	1	1	1	1	1	1	1	400 ml/daa
	Mancozeb	1	1	1	1	1	1	1	1	1	
Fastac 50	Alpha-cypermethrin	1	1	1	1	1	1	1	1	1	40 ml/daa
Karate 2.5 WG	Lambda-cyhalothrin	1	1	1	1	1	1	1	1	1	80 g/daa
Sumi-Alpha	Esfenvalerate	3	3	3	3	3	3	3	3	3	30 ml/daa
Reglone	Diquat dibromide	1	1	1	1	1	1	1	1	1	300 ml/daa

EPRIP score	EPRIP judgement	EPRIP judgement (value)
1	No	0
2-16	Negligible	1
17-81	Small	2
82-256	Present	3
257-400	Large	4
>400	Very large	5

Table VIII: Overall evaluation of all parameters (air, groundwater, soil and surface water) in connection with pesticide use in spring wheat production, Grue.

Merchandise	Active ingredient	ATm4	AFs5	FOs5	TLt5	KMk5	KGl5	KLr5	TKi5	THg5	Dose (NAD)
Actril 3-D	Ioxynil	1	1	1	1	1	1	1	1	1	300 ml/daa
	Dichlorprop - p	1	1	1	1	1	1	1	1	1	
	MCPA	1	1	1	1	1	1	1	1	1	
Ally 50 ST	Metsulfuron - methyl	1	1	1	1	1	1	1	1	1	1.2 g/daa
Ally Class 50 WG	Metsulfuron - methyl	1	1	1	1	1	1	1	1	1	5 g/daa
	Carfentrazone - ethyl	1	1	1	1	1	1	1	1	1	
Ariane S	Fluroxypyr-meptyl	1	1	1	1	1	1	1	1	1	250 ml/daa
	Clopyralid	1	1	1	1	1	1	1	1	1	
	MCPA	1	1	1	1	1	1	1	1	1	
Roundup ECO	Glyphosate	1	1	1	1	1	1	1	1	1	400 ml/daa
Express	Tribenuron - methyl	1	1	1	1	1	1	1	1	1	1 tabl./5 daa
Harmony Plus 50 T	Thifensulfuron - methyl	1	1	1	1	1	1	1	1	1	1.5 g/daa
	Tribenuron - methyl	1	1	1	1	1	1	1	1	1	
Hussar	Mefenpyr - diethyl	1	1	1	1	1	1	1	1	1	20 g/daa
	Iodosulfuron	1	1	1	1	1	1	1	1	1	
MCPA 750	MCPA	1	1	1	1	1	1	1	1	1	400 ml/daa
Optica Mekoprop - P	Mecoprop - p	1	1	1	1	1	1	1	1	1	300 ml/daa
Primus	Florasulam	1	1	1	1	1	1	1	1	1	10 ml/daa
Puma Extra	Fenoxaprop - p - ethyl	1	1	1	1	1	1	1	1	1	120 ml/daa
	Mefenpyr - diethyl	1	1	1	1	1	1	1	1	1	
Starane	Fluroxypyr-meptyl	1	1	1	1	1	1	1	1	1	200 ml/daa
Acanto Prima	Cyprodinil	1	1	1	1	1	1	1	1	1	150 g/daa
	Picoxystrobin	1	1	1	1	1	1	1	1	1	
Amistar	Azoxystrobin	1	1	1	1	1	1	1	1	1	100 ml/daa
Amistar Duo	Azoxystrobin	1	1	1	1	1	1	1	1	1	100 ml/daa
	Propiconazole	1	1	1	1	1	1	1	1	1	

Merchandise	Active ingredient	ATm4	AFs5	FOs5	TLt5	KMk5	KGl5	KLr5	TKi5	THg5	Dose (NAD)
Amistar Pro	Azoxystrobin	1	1	1	1	1	1	1	1	1	200 ml/daa
	Fenpropimorph	1	1	1	1	1	1	1	1	1	
Comet	Pyraclostrobin	1	1	1	1	1	1	1	1	1	100 ml/daa
Comet Plus	Fenpropimorph	1	1	1	1	1	1	1	1	1	200 ml/daa
	Pyraclostrobin	1	1	1	1	1	1	1	1	1	
Forbel	Fenpropimorph	1	1	1	1	1	1	1	1	1	100 ml/daa
Mentor	Fenpropimorph	1	1	1	1	1	1	1	1	1	50 ml/daa
	Kresoxim-methyl	1	1	1	1	1	1	1	1	1	
Stereo 312.5 EC	Propiconazole	1	1	1	1	1	1	1	1	1	150 ml/daa
	Cyprodinil	1	1	1	1	1	1	1	1	1	
Stratego 250 EC	Propiconazole	1	1	1	1	1	1	1	1	1	100 ml/daa
	Trifloxystrobin	1	1	1	1	1	1	1	1	1	
Stratego 312.5 EC	Propiconazole	1	1	1	1	1	1	1	1	1	100 ml/daa
	Trifloxystrobin	1	1	1	1	1	1	1	1	1	
Zenit 575 EC	Fenpropidin	1	1	1	1	1	1	1	1	1	100 ml/daa
	Propiconazole	1	1	1	1	1	1	1	1	1	
Fastac 50	Alpha cypermethrin	1	1	1	1	1	1	1	1	1	40 ml/daa
Karate 2.5 WG	Lambda - cyhalothrin	1	1	1	1	1	1	1	1	1	80 g/daa
Perfekthion 500 S	Dimethoate	1	1	1	1	1	1	1	1	1	80 ml/daa
Pirimor	Pirimicarb	1	1	1	1	1	1	1	1	1	50 g/daa
Sumi Alpha	Esfenvalerate	3	3	3	3	3	3	3	3	3	30 ml/daa

EPRIP score	EPRIP judgement	EPRIP judgement (value)
1	No	0
2-16	Negligible	1
17-81	Small	2
82-256	Present	3
257-400	Large	4
>400	Very large	5

Table IX: Risk classification of pesticides, applied in potato production, Grue. Water table thickness = 0.3m, water table depth: 1m, max. daily rainfall = 85mm

Merchandise	Active ingredient		ATm4	AFs5	FOs5	TLt5	KMk5	KGl5	KLr5	TKi5	THg5
		PEC -Groundwater (µg/L)									
Sencor	Metribuzin		2,18E-01	1,85E-01	1,49E-01	1,22E-01	1,94E-01	2,20E-01	1,85E-01	1,86E-01	1,77E-01
		Risk	4	3	3	3	3	4	3	3	3
Titus	Rimsulfuron		8,26E-03	7,43E-03	6,42E-03	5,88E-03	7,90E-03	8,45E-03	7,43E-03	7,49E-03	7,08E-03
		Risk	2	1	1	1	1	2	1	1	1

Table X: Risk classification of pesticides, applied in potato production, Grue. Water table thickness = 10m, water table depth: 3.75m, max. daily rainfall = 85mm

Merchandise	Active ingredient		ATm4	AFs5	FOs5	TLt5	KMk5	KGl5	KLr5	TKi5	THg5
		PEC -Groundwater (µg/L)									
Sencor	Metribuzin		3,76E-03	2,24E-03	1,16E-03	4,57E-04	2,19E-03	3,56E-03	2,24E-03	2,25E-03	2,20E-03
		Risk	2	1	1	1	1	2	1	1	1
Titus	Rimsulfuron		1,81E-04	1,34E-04	9,00E-05	5,42E-05	1,37E-04	1,80E-04	1,34E-04	1,35E-04	1,30E-04
		Risk	1	1	1	1	1	1	1	1	1

Table XI: Risk classification of pesticides, applied in spring wheat production, Grue. Water table thickness = 0.3m, water table depth = 1m, max. daily rainfall =85 mm

Merchandise	Active ingredient		ATm4	AFs5	FOs5	TLt5	KMk5	KGl5	KLr5	TKi5	THg5
		PEC -Groundwater (µg/L)									
Express	Tribenuron-methyl		7,24E-03	6,39E-03	5,42E-03	4,81E-03	6,77E-03	7,35E-03	6,39E-03	6,44E-03	6,09E-03
		Risk	2	1	1	1	1	2	1	1	1
MCPA 750	MCPA		2,53E+00	2,05E+00	1,55E+00	1,13E+00	2,14E+00	2,56E+00	2,05E+00	2,07E+00	1,98E+00
		Risk	4	4	4	4	4	4	4	4	4

Table XII: Risk classification of pesticides, applied in spring wheat production, Grue Water table thickness = 10m, water table depth = 3.75m, max. daily rainfall = 85mm

Merchandise	Active ingredient		ATm4	AFs5	FOs5	TLt5	KMk5	KGl5	KLr5	TKi5	THg5
		PEC -Groundwater (µg/L)									
Express	Tribenuron-methyl		1,48E-04	1,02E-04	6,35E-05	3,42E-05	1,02E-04	1,42E-04	1,02E-04	1,02E-04	9,87E-05
		Risk	1	1	1	1	1	1	1	1	1
MCPA 750	MCPA		3,55E-02	1,78E-02	7,24E-03	1,85E-03	1,70E-02	3,39E-02	1,78E-02	1,79E-02	1,81E-02
		Risk	3	2	1	1	2	3	2	2	2

1 = ingen risiko
2 = lav risiko
3 = moderat risiko
4 = høy risiko

Table XIII: Risk classifications and PEC for pesticides applied in potato production, Grue. (No calibrations)

Merchandise	Active ingredient		ATm4	AFs5	FOs5	TLt5	KMk5	KGl5	KLr5	TKi5	THg5
			PEC -Groundwater (µg/L)								
Rizolex 50 FW	Tolclofos methyl		2,62E-83	1,61E-133	9,52E-202	6,58E-319	8,14E-142	1,35E-85	1,61E-133	1,98E-134	4,10E-127
		Risk	1	1	1	1	1	1	1	1	1
Fenix	Aclonifen		4,41E-07	3,23E-10	1,74E-14	9,50E-22	1,06E-10	3,30E-07	3,23E-10	2,85E-10	7,68E-10
		Risk	1	1	1	1	1	1	1	1	1
Finale	Glufosinate-ammonium		2,21E-02	1,42E-02	8,52E-03	4,37E-03	1,40E-02	2,02E-02	1,43E-02	1,44E-02	1,37E-02
		Risk	3	2	1	1	2	3	2	2	2
Focus Ultra	Cycloxydim		1,41E-04	7,81E-06	1,73E-07	3,15E-10	5,03E-06	1,11E-04	7,82E-06	7,69E-06	1,02E-05
		Risk	1	1	1	1	1	1	1	1	1
Select	Clethodim		1,30E-04	1,80E-05	1,52E-06	2,95E-08	1,31E-05	9,55E-05	1,80E-05	1,80E-05	2,01E-05
		Risk	1	1	1	1	1	1	1	1	1
Sencor	Metribuzin		3,76E-03	2,24E-03	1,16E-03	4,57E-04	2,19E-03	3,56E-03	2,23E-03	2,25E-03	2,20E-03
		Risk	2	1	1	1	1	2	1	1	1
Titus	Rimsulfuron		1,81E-04	1,34E-04	9,00E-05	5,42E-05	1,37E-04	1,80E-04	1,34E-04	1,35E-04	1,30E-04
		Risk	1	1	1	1	1	1	1	1	1
Acrobat WG	Dimetomorph		1,22E-03	5,65E-04	1,98E-04	3,85E-05	5,37E-04	1,21E-03	5,65E-04	5,63E-04	5,85E-04
		Risk	2	1	1	1	1	2	1	1	1
	Mancozeb		0	0	0	0	0	0	0	0	0
		Risk	1	1	1	1	1	1	1	1	1
Dithane NewTec	Mancozeb		0	0	0	0	0	0	0	0	0
		Risk	1	1	1	1	1	1	1	1	1
Electis	Zoxamide		6,74E-05	5,79E-06	2,05E-07	7,79E-10	4,17E-06	6,19E-05	5,79E-06	5,59E-06	7,45E-06
		Risk	1	1	1	1	1	1	1	1	1
	Mancozeb		0	0	0	0	0	0	0	0	0
		Risk	1	1	1	1	1	1	1	1	1
Sereno WG	Fenamidone		4,04E-07	1,58E-09	9,01E-13	2,95E-18	6,68E-10	2,99E-07	1,58E-09	1,45E-09	2,95E-09
		Risk	1	1	1	1	1	1	1	1	1
	Mancozeb		0	0	0	0	0	0	0	0	0
		Risk	1	1	1	1	1	1	1	1	1
Shirlan	Fluazinam		8,32E-18	5,66E-27	2,02E-39	9,86E-61	1,83E-28	3,17E-18	5,66E-27	3,90E-27	7,88E-26
		Risk	1	1	1	1	1	1	1	1	1
Tattoo	Propamocarb		1,60E-03	3,03E-04	3,17E-05	7,73E-07	2,48E-04	1,51E-03	3,03E-04	2,97E-04	3,51E-04
		Risk	2	1	1	1	1	2	1	1	1
	Mancozen		0	0	0	0	0	0	0	0	0
		Risk	1	1	1	1	1	1	1	1	1
Fastac 50	Alpha-cypermethrin		2,14E-140	4,57E-225	0	0	4,84E-239	3,99E-144	4,57E-225	1,28E-226	3,36E-214
		Risk	1	1	1	1	1	1	1	1	1
Karate 2.5 WG	Lambda-cyhalothrin		0	0	0	0	0	0	0	0	0
		Risk	1	1	1	1	1	1	1	1	1
Sumi-Alpha	Esfenvalerate		3,82E-14	2,47E-20	9,43E-29	3,79E-43	2,52E-21	2,07E-14	2,47E-20	1,92E-20	1,45E-19
		Risk	1	1	1	1	1	1	1	1	1
Reglone	Diquat dibromide		2,28E-182	3,45E-294	0	0	1,18E-312	2,75E-187	3,45E-294	3,06E-296	7,94E-280
		Risk	1	1	1	1	1	1	1	1	1

1 = no risk
2 = low risk
3 = moderate risk
4 = high risk

Table XIV: Risk classifications and PEC for pesticides applied in spring wheat production, Grue. (No calibrations)

Merchandise	Activ ingredient		ATm4	AFs5	FOs5	TLt5	KMk5	KGl5	KLr5	TKi5	THg5
		PEC -Groundwater (µg/L)									
Actril 3-D	Ioxynil		8,35E-07	2,97E-09	1,54E-12	4,33E-18	1,22E-09	5,94E-07	2,97E-09	2,73E-09	5,54E-09
		Risk	1	1	1	1	1	1	1	1	1
	Dichlorprop - p		8,22E-03	5,07E-03	2,73E-03	1,14E-03	5,00E-03	7,89E-03	5,07E-03	5,10E-03	4,99E-03
		Risk	2	1	1	1	1	2	1	1	1
	MCPA		3,34E-03	1,68E-03	6,81E-04	1,74E-04	1,60E-03	3.19e-03	1,68E-03	1,68E-03	1,70E-03
		Risk	2	1	1	1	1	2	1	1	1
Ally 50 ST	Metsulfuron - methyl		8,15E-05	4,43E-05	2,05E-05	6,64E-06	4,25E-05	7,61E-05	4,43E-05	4,45E-05	4,40E-05
		Risk	1	1	1	1	1	1	1	1	1
Ally Class 50 WG	Metsulfuron - methyl		6,79E-05	3,65E-05	1,71E-05	5,54E-06	3,54E-05	6,34E-05	3,69E-05	3,71E-05	3,67E-05
		Risk	1	1	1	1	1	1	1	1	1
	Carfentrazone - ethyl		4,83E-09	2,03E-12	2,03E-16	7,31E-23	3,95E-13	7,70E-10	2,05E-12	2,08E-12	3,15E-12
		Risk	1	1	1	1	1	1	1	1	1
Ariane S	Fluroxypyr-meptyl		1,35E-104	1,40E-167	3,02E-253	0	5,71E-178	2,24E-107	1,40E-167	9,85E-169	1,66E-159
		Risk	1	1	1	1	1	1	1	1	1
	Clopyralid		1,55E-03	1,42E-03	1,28E-03	1,27E-03	1,51E-03	1,56E-03	1,42E-03	1,44E-03	1,35E-03
		Risk	2	1	1	1	1	2	1	1	1
	MCPA		5,92E-03	2,97E-03	1,21E-03	3,09E-04	2,84E-03	5,65E-03	2,97E-03	2,98E-03	3,01E-03
		Risk	2	1	1	1	1	2	1	1	1
Roundup ECO	Glyphosate		4,12E-151	1,05E-243	0	0	5,39E-259	3,29E-155	1,05E-243	2,13E-243	7,99E-232
		Risk	1	1	1	1	1	1	1	1	1
Express	Tribenuron - methyl		1,48E-04	1,02E-04	6,35E-05	3,42E-05	1,02E-04	1,42E-04	1,02E-04	1,02E-04	9,87E-05
		Risk	1	1	1	1	1	1	1	1	1
Harmony Plus 50 T	Thifensulfuron - methyl		3,05E-05	9,78E-06	2,45E-06	2,95E-07	8,33E-06	2,48E-05	9,79E-06	9,85E-06	1,00E-05
		Risk	1	1	1	1	1	1	1	1	1
	Tribenuron - methyl		4,93E-05	3,39E-05	2,12E-05	1,14E-05	3,41E-05	1,42E-04	3,40E-05	3,42E-05	3,30E-05
		Risk	1	1	1	1	1	1	1	1	1
Hussar	Mefenpyr - diethyl		9,49E-07	1,21E-08	3,27E-11	1,52E-15	6,28E-09	7,77E-07	1,21E-08	1,13E-08	1,96E-08
		Risk	1	1	1	1	1	1	1	1	1
	Iodosulfuron		9,52E-05	4,13E-05	1,43E-05	2,85E-06	3,80E-05	8,64E-05	4,13E-05	4,14E-05	4,20E-05
		Risk	1	1	1	1	1	1	1	1	1
MCPA 750	MCPA		3,55E-02	1,78E-02	7,24E-03	1,85E-03	1,70E-02	3,39E-02	1,78E-02	1,79E-02	1,81E-02
		Risk	3	2	1	1	2	3	2	2	2
Optica Mekoprop - P	Mecoprop - p		2,39E-02	1,27E-02	5,84E-03	1,89E-03	1,21E-02	2,19E-02	1,27E-02	1,28E-02	1,26E-02
		Risk	3	2	1	1	2	3	2	2	2
Primus	Florasulam		8,56E-05	5,36E-05	3,04E-05	1,41E-05	5,24E-05	7,94E-05	5,36E-05	5,41E-05	5,21E-05
		Risk	1	1	1	1	1	1	1	1	1
Puma Extra	Fenoxaprop - p - ethyl		0	0	0	0	0	0	0	0	0
		Risk	1	1	1	1	1	1	1	1	1
	Mefenpyr - diethyl		2,89E-06	3,67E-08	9,95E-11	4,63E-15	1,91E-08	2,36E-06	3,67E-08	3,43E-08	5,97E-08
		Risk	1	1	1	1	1	1	1	1	1
Starane	Fluroxypyr-meptyl		4,85E-104	5,04E-167	1,09E-252	0	2,05E-177	8,06E-107	5,04E-167	3,55E-168	5,96E-159
		Risk	1	1	1	1	1	1	1	1	1
Acanto Prima	Cyprodinil		2,28E-06	9,37E-09	5,35E-12	1,69E-17	4,07E-09	1,82E-06	9,37E-09	8,56E-09	1,78E-08
		Risk	1	1	1	1	1	1	1	1	1
	Pikoxystrobin		7,40E-07	3,41E-09	2,32E-12	9,97E-18	1,50E-09	5,82E-07	3,41E-09	3,13E-09	6,34E-09
		Risk	1	1	1	1	1	1	1	1	1
Amistar	Azoxystrobin		2,59E-03	1,21E-03	4,29E-04	8,53E-05	1,15E-03	2,57E-03	1,21E-03	1,20E-03	1,25E-03
		Risk	2	1	1	1	1	2	1	1	1
Amistar Duo	Azoxystrobin		2,07E-03	9,68E-04	3,44E-04	6,83E-05	9,23E-04	2,05E-03	9,68E-04	9,64E-04	1,00E-03
		Risk	2	1	1	1	1	2	1	1	1
	Propiconazole		1,58E-03	8,35E-04	3,49E-04	9,14E-05	8,15E-04	1,58E-03	8,35E-04	8,33E-04	8,53E-04
		Risk	2	1	1	1	1	2	1	1	1

Table XIV: Risk classifications and PEC for pesticides applied in spring wheat production, Grue. (No calibrations). Continuance…

Merchandise	Active ingredient		ATm4	AFs5	FOs5	TLt5	KMk5	KGl5	KLr5	TKi5	THg5
Amistar Pro	Azoxystrobin		2,07E-03	9,68E-04	3,44E-04	6,83E-05	9,23E-04	2,05E-03	9,68E-04	9,64E-04	1,00E-03
		Risk	2	1	1	1	1	2	1	1	1
	Fenpropimorph		9,80E-13	3,90E-19	7,75E-28	1,01E-42	3,67E-20	5,19E-13	3,90E-19	3,01E-19	2,43E-18
		Risk	1	1	1	1	1	1	1	1	1
Comet	Pyraclostrobin		3,74E-31	8,95E-49	9,71E-73	7,38E-114	1,17E-51	6,32E-32	8,95E-49	4,29E-49	1,55-46
		Risk	1	1	1	1	1	1	1	1	1
Comet Plus	Fenpropimorph		1,31E-12	5,22E-19	1,04E-27	1,35E-42	4,92E-20	6,95E-13	5,23E-19	4,03E-19	3,26-18
		Risk	1	1	1	1	1	1	1	1	1
	Pyraclostrobin		2,99E-31	7,16E-49	7,77E-73	5,91E-114	9,38E-52	5,06E-32	7,16E-49	3,44E-49	1,24-46
		Risk	1	1	1	1	1	1	1	1	1
Forbel	Fenpropimorph		1,31E-12	5,22E-19	1,04E-27	1,35E-42	4,92E-20	6,95E-13	5,23E-19	4,03E-19	3,26E-18
		Risk	1	1	1	1	1	1	1	1	1
Mentor	Fenpropimorph		2,63E-13	1,04E-19	2,07E-28	2,71E-43	9,84E-21	1,39E-13	1,05E-19	8,06E-20	6,51E-19
		Risk	1	1	1	1	1	1	1	1	1
	Kresoxim-methyl		5,90E-05	5,61E-06	2,26E-07	1,13E-09	3,99E-06	5,25E-05	5,51E-06	5,35E-06	6,94E-06
		Risk	1	1	1	1	1	1	1	1	1
Stereo 312.5 EC	Propiconazole		1,18E-03	6,26E-04	2,62E-04	6,86E-05	6,11E-04	1,19E-03	6,26E-04	6,25E-04	6,40E-04
		Risk	2	1	1	1	1	2	1	1	1
	Cyprodinil		1,90E-06	7,81E-09	4,46E-12	1,40E-17	3,39E-09	1,52E-06	7,81E-09	7,13E-09	1,48E-08
		Risk	1	1	1	1	1	1	1	1	1
Stratego 250 EC	Propiconazole		1,58E-03	8,35E-04	3,49E-04	9,14E-05	8,15E-04	1,58E-03	8,35E-04	8,33E-04	8,53E-04
		Risk	2	1	1	1	1	2	1	1	1
	Trifloxystrobin		3,50E-31	1,21E-48	2,34E-72	5,04E-114	1,65E-51	5,53E-32	1,21E-48	5,91E-49	1,95E-46
		Risk	1	1	1	1	1	1	1	1	1
Stratego 312.5 EC	Propiconazole		1,58E-03	8,35E-04	3,49E-04	9,14E-05	8,15E-04	1,58E-03	8,35E-04	8,33E-04	8,53E-04
		Risk	2	1	1	1	1	2	1	1	1
	Trifloxystrobin		5,26E-31	1,82E-48	3,51E-72	7,55E-113	2,47E-51	8,29E-32	1,82E-48	8,86E-49	2,92E-46
		Risk	1	1	1	1	1	1	1	1	1
Zenit 575 EC	Fenpropidin		5,02E-06	3,37E-08	3,72E-11	3,62E-16	1,59E-08	4,14E-06	3,37E-08	3,11E-08	6,03E-08
		Risk	1	1	1	1	1	1	1	1	1
	Propiconazole		1,58E-03	8,35E-04	3,49E-04	9,14E-05	8,15E-04	1,58E-03	8,35E-04	8,33E-04	8,53E-04
		Risk	2	1	1	1	1	2	1	1	1
Fastac 50	Alpha-cypermethrin		3,21E-140	6,85E-225	0	0	7,26E-239	5,98E-144	6,86E-225	1,92E-226	5,04E-214
		Risk	1	1	1	1	1	1	1	1	1
Karate 2.5 WG	Lambda - cyhalothrin		0	0	0	0	0	0	0	0	0
		Risk	1	1	1	1	1	1	1	1	1
Perfekthion 500 S	Dimethoate		8,39E-04	1,35E-04	1,45E-05	4,34E-07	9,98E-05	5,98E-04	1,35E-04	1,36E-04	1,46E-04
		Risk	1	1	1	1	1	1	1	1	1
Pirimor	Pirimicarb		3,48E-03	1,95E-03	8,87E-04	2,70E-04	1,92E-03	3,48E-03	1,95E-03	1,95E-03	1,97E-03
		Risk	2	1	1	1	1	2	1	1	1
Sumi Alpha	Esfenvalerate		5,72E-14	3,70E-20	1,41E-28	5,68E-43	3,78E-21	3,11E-14	3,70E-20	2,88E-20	2,17E-19
		Risk	1	1	1	1	1	1	1	1	1

1 = no risk
2 = low risk
3 = moderate risk
4 = high risk